CEP

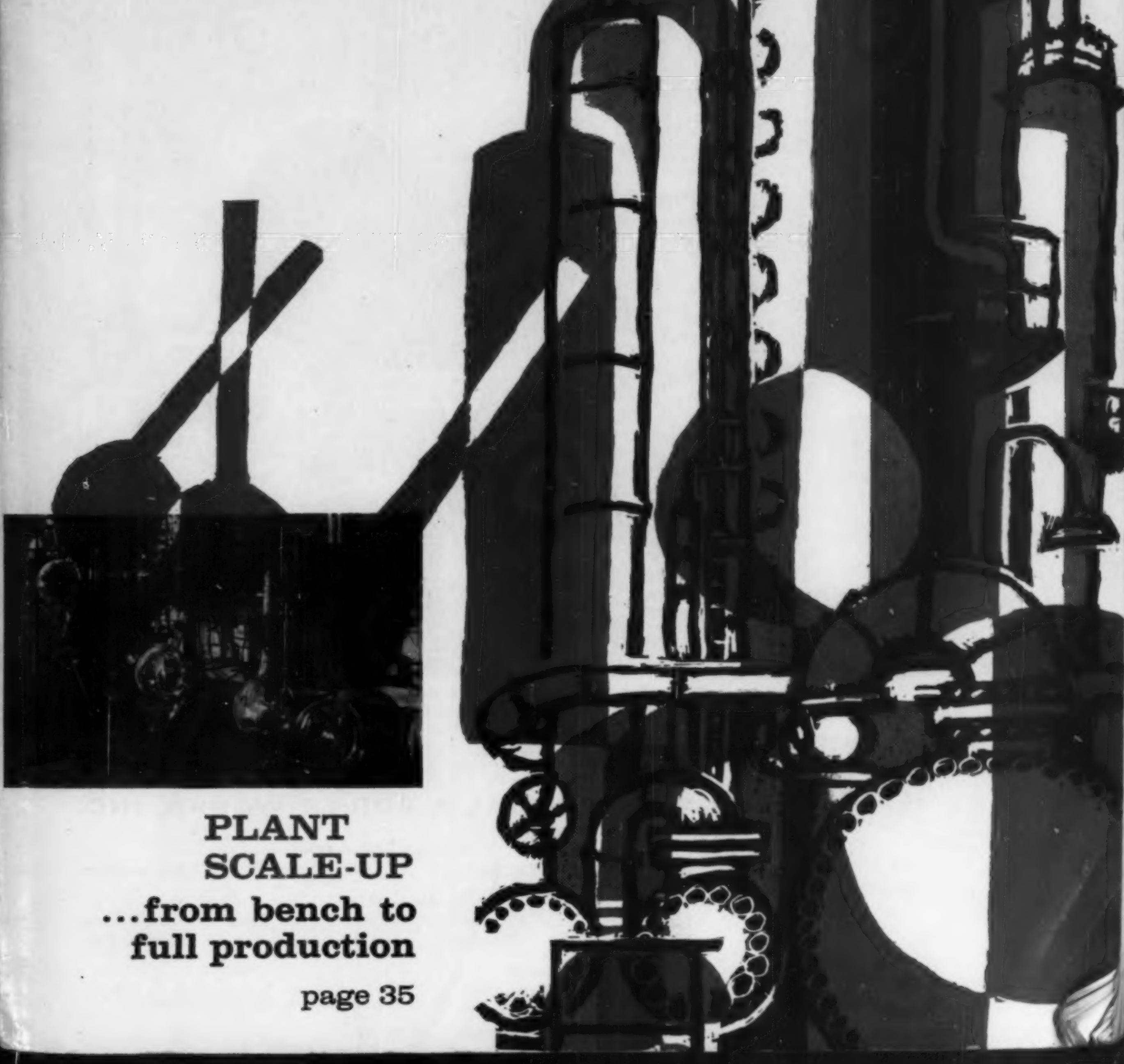
CHEMICAL ENGINEERING PROGRESS

SEPTEMBER SPECIALS

• Heavy Water: the "Spevack" Process—page 70

• Dimensionless Numbers: 10-page Analysis—page 55

SEPTEMBER 1959



PLANT SCALE-UP

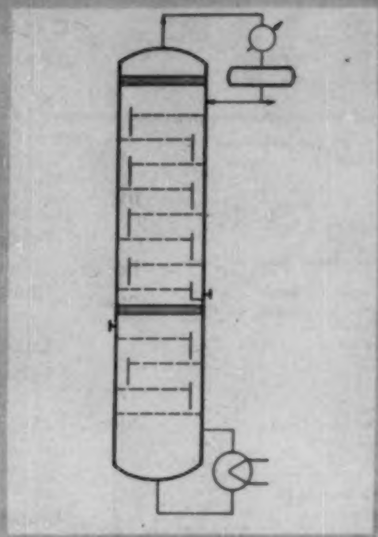
...from bench to full production

page 35

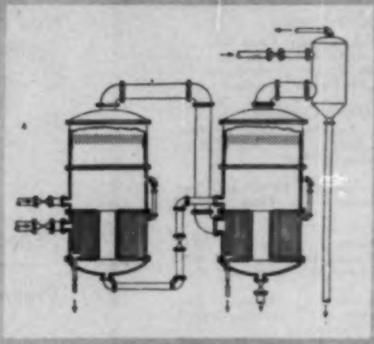
YORKMESH DEMISTERS®

will improve

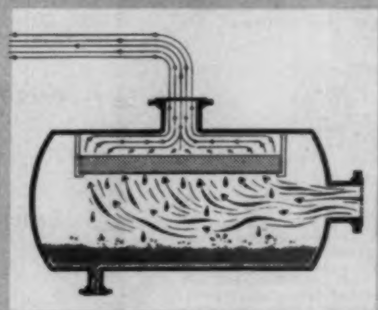
PROCESS VESSEL PERFORMANCE



The efficiency of separation and thruput capacity of distillation equipment can be significantly improved by the use of YORKMESH DEMISTERS.



YORKMESH DEMISTERS installed in evaporators avoid product loss and provide clean condensate.



YORKMESH DEMISTERS installed in Knock-Out Drums result in high separation efficiency at low pressure drop.

It will pay you to investigate YORKMESH DEMISTERS if your process vessels need a lift in efficiency. The versatile knitted wire-mesh pads are being used more and more throughout industry to *stop* liquid entrainment and improve the performance of:

Vacuum Towers, Distillation Equipment, Gas Absorbers, Scrubbers, Evaporators, Knock-Out Drums, Steam Drums and many others.

Here is what happens when YORKMESH DEMISTERS are installed:

1. As vapor disengages from liquid it carries with it fine liquid droplets.
2. When the vapor stream passes thru the fine wire mesh, the liquid droplets impinge on the wire surfaces, coalesce in to large drops, and fall.
3. The vapor is now dry and free from entrained liquid.

Send us details on your type of process vessel or operation, vapor flow rate, pressure, temperature, and density or molecular weight; approximate amount of entrained liquid, viscosity, and specific gravity . . . for existing equipment advise dimensions, indicate vertical or horizontal vessel and material of construction required for mesh and grids. Complete details will make it possible for us to present our recommendations and quotation.

—Write for Bulletin #21—

YORK

OTTO H. YORK CO., INC.
6 CENTRAL AVE. • WEST ORANGE, N. J.

For more information, turn to Data Service card, circle No. 95

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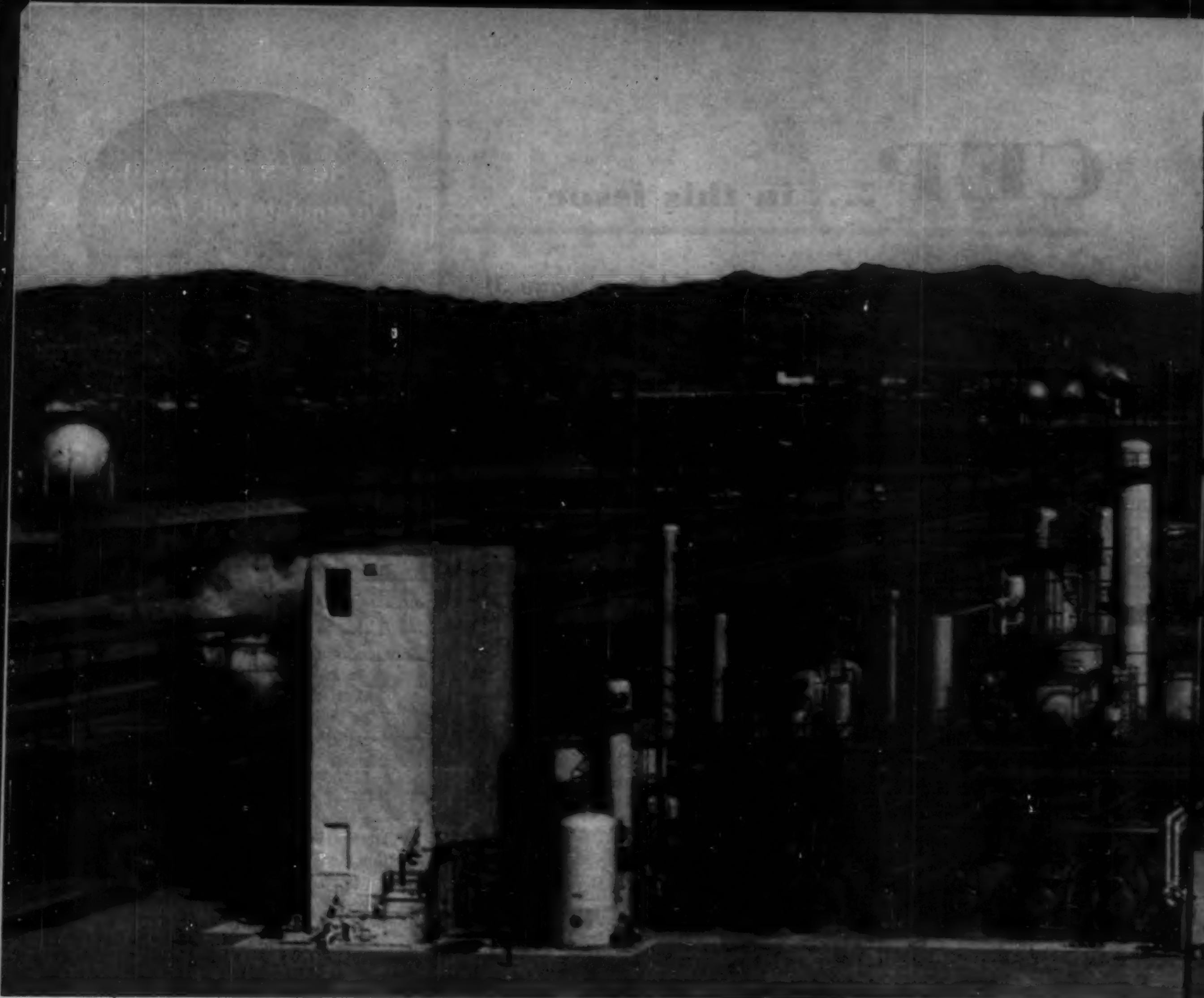
(Continued from page 3)

departmental features

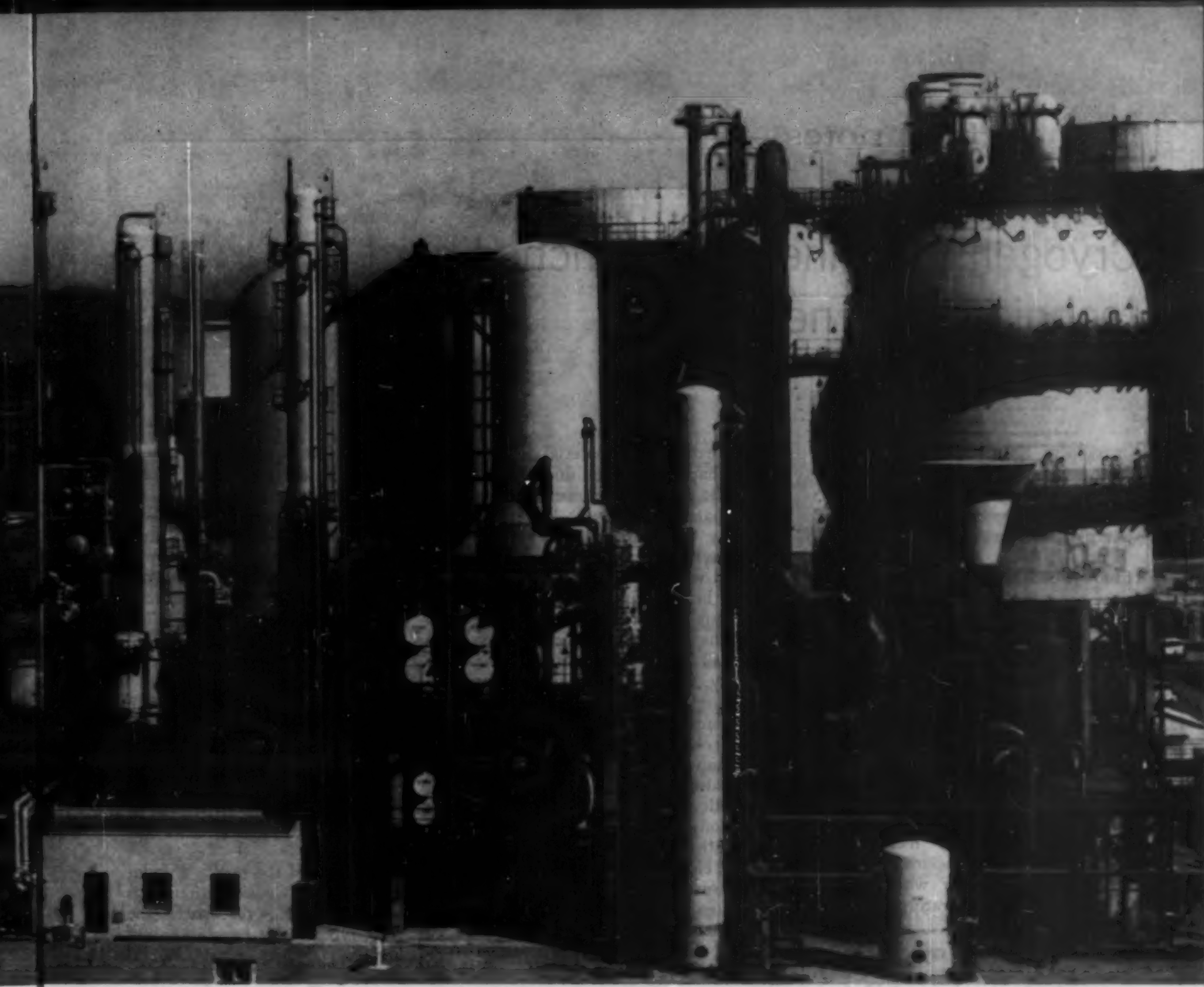


What's new in cat crackers?

The art of catalytic cracking has reached a highly advanced state. The improvements and refinements that now take place as new crackers are built seem minor indeed when one recalls the series of spectacular breakthroughs that followed one after another during cat-cracking's first eventful decade.

Yet there is drama even today. Sometimes it takes the form of a successful race against time. A record of sorts was set recently when the unit above was completed by Fluor for Standard Oil Company of California at its Richmond refinery on San Francisco Bay. It is an Esso Model IV





Fluid Catalytic Cracker with a capacity of 55,000 barrels per day, and it was delivered to the customer in time for the summer marketing season—two weeks less than one year after work began.

It is one of the two largest Model IV's in existence. The other, of the same capacity, was built by Fluor in 1954 for Standard at El Segundo. The Richmond and El Segundo units are almost identical except for auxiliaries (Richmond has a fired heater, a CO boiler and water-treating facilities). A few minor design and material changes, based on experience at El Segundo, were incorporated into the new unit.

The job was begun on June 2, 1958, and completed May 15, 1959. Credit for the fast completion is due to many factors—organization, planning, fine co-operation from customer and suppliers, and good luck. But perhaps the most important element of all was Fluor's broad experience in the design, engineering and construction of cat crackers—nearly thirty of them since 1940.

A Fluor brochure, "FCC at Richmond," describes this interesting unit. Write to Dept. 51, The Fluor Corporation, Ltd., 2500 South Atlantic Boulevard, Los Angeles 22, California.

When you consider expansion...
the most important investment you can make
is in the creative ability of men

FLUOR

Engineers & Constructors

For more information, circle No. 63

marginal notes

Cryogenic engineering, Punched card techniques, in new books

CRYOGENIC ENGINEERING, Russell B. Scott, Chief, National Bureau of Standards Cryogenic Engineering Laboratory, prepared for the Atomic Energy Commission, D. Van Nostrand Company, Inc., New York, N. Y., (1959), 368 p., $5.60.

Reviewed by Clyde McKinley, Air Products, Inc., Allentown, Pa.

Mr. Scott's work of over three decades with the basic properties of materials at low temperatures and the associated engineering applications of such properties, has prepared him eminently for the writing of *Cryogenic Engineering*. The objective of his book, that of presenting a broad and relatively comprehensive understanding of cryogenic techniques—together with the associated data and theory—to the reader who is unfamiliar with low temperature, has been admirably met.

A treatise of the cryogenic engineering field has not previously been prepared. Facets of the field have been covered in such publications as *Separation of Gases* — Ruhemann, *Chemical Engineers' Handbook*—low temperature process portion of Section 25—Dodge, *Handbuch der Kaltetechnik*—R. Plank, National Bureau of Standards publications, American Society for Testing Materials publications, *Low Temperature Physics*—C. Squire, etc.

Scott has here assembled material which he thought should be most valuable in helping people with cryogenic engineering problems, both in engineering design and in laboratory operations. The subject matter of the book is presented principally in nine chapters — Liquefaction of Gases, Separation of Gases, Cooling by Adiabatic De-magnetization, Low Temperature Thermometry, Insulation, Storing and Transporting Liquefied Gases, Transfer of Liquefied Gases, Properties of Cryogenic Fluids, and Low Temperature Properties of Structural Materials.

The treatment of material is new and all chapters are well documented with bibliographic references. Subject matter handling is typically represented by the chapter on insulation. The behavior of vacuum insulation is described with a discussion of the associated heat transfer which occurs by gaseous conduction, by radiation, and by the support members between the vessel walls. The problems of emissivity, vacuum systems, pumping speed, outgassing, getters, cold traps and vacuum gages are covered in some detail. Techniques for the construction of vacuum insulated equipment are also treated—including materials of construction, joint designs, electrical connections through vacuum spaces, leak hunting and repairing, etc. The chapter closes with information on the measurement of insulation values at low temperature.

Cryogenic Engineering will be useful to all those interested in low temperature engineering problems.

PUNCHED CARDS—THEIR APPLICATION TO SCIENCE AND INDUSTRY, Edited by Robert S. Casey, James W. Perry, Allen Kent and Madaline Berry. Second Edition, Reinhold Publishing Corp., New York, N. Y., (1958), 697 p., $15.00.

Reviewed by Eugene Wall, Engineering Service Division, E. I. du Pont de Nemours & Co., Wilmington, Del.

The first (1951) edition of this book had the stated objective of assisting the individual scientist, engineer or other technologist in applying punched-card techniques in solving problems of information storage and retrieval. This second edition has the same objective. Accordingly, the reader should not expect (based upon the title of the book) that more than cursory treatment will be given to punched-card techniques for purposes *other than information storage and retrieval*. Further, because of the objective of assisting *individuals* rather than organized information systems or services, the book treats edge-punched cards (McBee, etc.) more extensively than it treats field-punched (IBM, etc.) cards—perhaps more extensively than the over-all relative utilities of the two types of cards would justify. It is thus apparent that the book has, after a fashion, attained one objective; it is of limited usefulness to organizations planning or operating systems involving large collections of documents.

The volume is divided into four parts: "Fundamental Machine Considerations," "Practical Applications," "Fundamental Considerations in Coding and System Design," and "Future Possibilities." In addition, there is an extensive bibliography (677 references).

The first part of the book, "Fundamental Machine Considerations," is well-organized; it discusses the available types and capabilities of punched-card devices. Parts II, III and IV are composed of 26 individual papers by 30 authors. The opinions expressed seem to be those of the authors; it appears that the editors felt it impossible to exercise any critical control over or evaluation of the significance, value and correctness of the conclusions which were drawn. Under such circumstances, it is not surprising that Parts II, III and IV are not cohesive, but more important, the reader must be wary of accepting at face value any of the varying conclusions drawn or implied by the different authors. Accordingly, the book may well serve best as background material, particularly as an illustration to the novice that he needs to do a great deal of fundamental thinking of his own (more than did many of the contributors) before he "freezes" the design of his own system.

It is unfortunate that the book leaves the impression that there are no fundamental, underlying principles in the field of information storage and retrieval, that each must go his own

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marginal notes

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way, that the works of those individually active in the field have only fortuitous common grounds. There does exist a set of fundamental principles, but they will not be apparent to the casual reader of this book. This is probably because the editors and most of the contributors were what we may call "machine-oriented."

The "machine-oriented" approach to information retrieval is analogous to the following approach to the design of a synthetic polymer plant: "Here is a catalog of used process equipment; build me a polyethylene plant using this equipment." The process developed then depends *only* upon the available equipment or patch-work modifications thereof. A more profitable approach would be to develop a process and *then* to design the equipment (using standard equipment where possible, of course).

The "machine-oriented" approach becomes evident early in Chapter 1, wherein Table 1-1 purports to classify "the newer tools and systems for literature searching." A number of conclusions drawn in this table are erroneous in matter of *degree* and some are entirely untenable. This is because the authors have chosen as their main classificatory headings the different types of available *devices*. In fact, *any* of these devices *can* be used for *any* literature retrieval purpose, the choice among them being purely one of economics, which vary with the environment. A better approach would have been to classify broadly the environments and then to discuss the devices most appropriate for each sort of environment.

Chapter II is an excellent summary by Casey of the mechanics of edge-punched cards and of their coding. The reader must take care not to confuse *coding* with *subject analysis*; coding is the creation of a one-to-one relationship between machine language and indexing terms—once the latter have been chosen during subject analysis. Chapter III describes available punched-card equipment and the available types of edge-punched and field-punched cards; the treatment of the latter is relatively superficial. Chapter III also gives a brief description of "Uniterm" and Batten card ("Peek-a-boo") systems.

Part II consists of 14 individually authored descriptions of "practical applications"; as noted above, each application is for a particular environment and in nearly every instance

continued on page 12

EIMCO design and production PROGRESS REPORT

B-305

Process Engineers, Inc., division of The Eimco Corporation: 420 Peninsular Ave., San Mateo, Calif.

World's Largest Covered Thickeners in Operation At U. S. Borax & Chemical

Four 230 ft. dia. Eimco-Process heavy-duty thickeners have been in operation for over a year at the United States Borax and Chemical Corporation refinery in Boron, California. These totally enclosed and insulated thickeners, largest of their kind in the world, are part of the CCD circuit from which the strong Borax solution goes to crystallization.

The thickener designs, developed in close cooperation with Pacific Coast Borax Division personnel and the engineering constructors, are custom-adaptations of Eimco-Process Type CX mechanisms. The cover of each unit is supported from radial trusses receiving central support from an 8 ft. dia. concrete column with steel shell that also carries the entire weight and torque of the thickener mechanism. The drive-head with split main gear and bearing was designed to the specific requirement of providing easy maintenance access. A special liquid seal was devised to protect the drive unit from tank vapors, as well as to ensure close control of process conditions.

Four totally enclosed Eimco-Process thickeners at Boron, California

Other installation features were the resting of the steel thickener tanks on oiled sand for corrosion prevention; continuous torque recording; and handling the thickener underflows with steam driven reciprocating pumps.

This $20,000,000 processing plant, on an 80 acre desert site, was designed and constructed by Southwestern Engineering Company and Ford J. Twaits Company as a joint venture. It has substantially increased the U. S. Borax capacity and is playing an important part in the production of high energy boron fuels for the space age.

NEW BULLETIN AVAILABLE

We recently completed an eight page bulletin describing our thickeners, hydroseparators, air-lift agitators, reactor-thickeners, slurry mixers and related equipment. It also covers recent design innovations such as our unique Thixo arms and platform lifting devices, and should be in your reference library even if your immediate plans do not include thickening equipment.

A request will bring one by return mail, or, if your plans *do* involve thickeners, our nearest sales engineer will deliver a copy in person.

Eimco Filtration Equipment Plays Important Role in Producing Rocket Fuels

At another plant, producing high energy fuels, engineers were faced with a troublesome filtration problem. They had to filter a fuel having an extremely low slurry viscosity, a high percentage of hydrogen in the gas, and containing a dangerously flammable material.

This problem was referred to Eimco's Research and Development center at Palatine, Illinois. Here, the Company's filtration research engineers, after a series of tests, were able to work out special adaptations for a continuous pressure drum filter that met all the specialized application requirements.

Continuous pressure drum filter of the type developed for the filtration of rocket fuels

Pressure test techniques were used to determine the correct size of the unit. Intricate seals were devised to keep air out of the pressure vessel. Changes were made in the hydraulic system. And, the filter was furnished with complete instrumentation.

This is typical of how Eimco's unexcelled research facilities and valuable backlog of experience in engineering custom-designed filter equipment can solve difficult filtration problems.

For more information, turn to Data Service card, circle No. 61

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there is no guarantee that the application is optimum even for its own environment. Uses of edge-punched (including Zatocode) cards, field-punched cards, Batten cards and "Uniterm" cards (which, incidentally, are not punched at all) are discussed. Various other systems and devices of minor importance are also described. The "high-spots" (as well as several distinct "low-spots") of the book occur in Part III, "Fundamental Considerations in Coding and Systems Design." Chapter 21, by Carl S. Wise, is an outstanding mathematical analysis of coding (*not* subject analysis) systems. Direct, selector, sequence and superimposed codes are all analyzed for efficiency and effectiveness. This chapter alone may be worth the price of the book to one engaged in installing or operating an information retrieval system.

Also, Chapter 22, by D. E. H. Frear, will prove invaluable to those beginning work in the chemical documentation field; it provides a concise description of the 12 best-known and most-widely used coding schemes for chemical compounds. It is unfortunate that none of these schemes ideally satisfies the requirements of unambiguous translation from chemical structure to code (and vice versa) while still allowing for generic searches.

The book closes as it opened—with the "machine-oriented" viewpoint.

Scheme for a Full-Time Course in Chemical Engineering, The Institution of Chemical Engineers, London, Eng., 16 p., 2 shillings ($0.28).

The purpose of this pamphlet published in England is to encourage the setting up of university courses leading to a degree in chemical engineering. Of considerable interest as a measure of the present state of the profession in England, and as a look at the potential future of the profession there.

Survey of State Legislation Relating to Higher Education (July 1, 1957 to June 30, 1958), E. V. Hollis, W. G. Land, and S. V. Martorana, U. S. Dept. of Health, Education, and Welfare, Office of Education, Washington, D. C., 115 p., $0.70.

Copies of this highly interesting survey may be obtained by writing to the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

For more information, turn to Data Service card, circle No. 43

For more information, turn to Data Service card, circle No. 114

Financing bottleneck seen by 1967

American industry may have serious trouble in financing the large-scale production facilities which, by 1967, the nation will need to meet the demands of a much enlarged population, said recently Dupont vice-president T. C. Davis.

"One reason for . . . pessimism," pointed out Davis, "is the fact that industry must operate in an inflation economy under an unrealistic depreciation policy. And, in spite of this, there is a continuing unwillingness on the part of the United States Treasury and the accounting profession to support suitable revisions of the income tax law which would permit sufficient depreciation allowances for income tax purposes."

Davis went on to explain that tax laws permit a company to set aside enough income over the years to recover the cost of equipment by the time it wears out. This would work if prices stood still, but they don't. Today, when equipment wears out, the money the government permits to be set aside for replacement is not enough to pay for the new because inflation has boosted the price of new equipment.

Since 1941, according to the speaker, the dollar has withered to only 41 cents and, if inflation keeps up, its worth may by 35 cents or less by 1967. "And," he continued, "by then, there is hardly an industrial plant now in operation that will not need considerable overhauling, if not replacing. Where are we going to get the money? Certainly not from our depreciation allowances. What we need is a new tax rule which will allow us to recover, through depreciation allowances, the original investment in terms of current purchasing power. The recovered capital could then be used to replace wornout and outmoded equipment."

Three alternatives are seen by Davis to a revised depreciation allowance policy, none of them particularly attractive:

- Raise prices to make up the difference in cost of replacement. But this would add to inflation and make things worse, he pointed out. Under present laws, in order to get one extra dollar to replace equipment, industry must earn $2.08, and to get that, prices must be raised accordingly.
- Neglect needed replacements, reduce the size of operations. "Naturally," said Davis, "the business will contract, so will the number of jobs, and so will profits."
- Raise the money by a combination of borrowing, reducing dividends, and taking "painful measures" to reduce wages. "As for borrowing," said Davis, "debt never solved any problem and often has created new ones." He went on to emphasize that earnings are the only significant element in the economy which have not moved upward since the war, and that reduced dividends "will drive away investors and send into hiding the money we may need to expand or operate." As for reducing wages—"that's a distressing prospect and I hope we won't have to face it."

Washington notes

AEC has awarded 22 contracts for development of new and improved industrial uses for radioisotopes and high-level radiation. . . . A new Bureau of Mines publication "Biblography of Investment and Operating Costs for Chemical and Petroleum Plants, January-December, 1957," Information Circular 7884, can be had from Superintendent of Documents, Government Printing Office, Washington 25, D.C. Price: 40¢ . . . A one-day unclassified symposium for industry representatives on development and potential uses of nuclear reactors for production of low-temperature process heat will be held in the AEC auditorium at Germantown, Maryland, October 1, 1959, beginning at 9:00 A.M. All interested persons are invited to attend. AEC will also sponsor a two-day symposium for management and technical personnel in the reprocessing of nuclear fuels, at Richland, Washington, October 20-21, 1959.

J. L. Gillman, Jr.

Chemical engineers in pulp and paper

To assure a future supply of chemical engineers for the pulp and paper industry;

To stimulate interest of Chemical Engineering Departments in the technology of pulp and paper manufacture;

To encourage the inclusion of problems, discussions, and examinations on pulp and paper technology in current chemical engineering curricula;

To expand fundamental and design data by increasing sponsored research in Chemical Engineering Departments.

These are the objectives of an educational promotion program concerning chemical engineering in the pulp and paper industry recently undertaken by the Chemical Engineering Committee of the Technical Association of the Pulp and Paper Industry (TAPPI).

First approach to the problem was to determine the number of chemical engineers holding formal degrees who are employed in the pulp and paper industry. Accordingly, questionnaires were distributed to 792 pulp and paper mills in the United States. Replies were received from 235 companies (264 mills) which corresponds to a 33 percent return.

Table A

Mill Category	B.S.	M.S.	Ph.D.	Total
92 paper mills	210	13	4	227
146 pulp and paper mills	1060	149	15	1224
26 unidentified mills	59	9	2	70
264 mills	1329	171	21	1521

Returns were divided into three catagories: paper mills only (92); pulp and paper mills (146); and unidentified mills (26). A total of 1,521 people with formal degrees in chemical engineering were shown to be employed by the 264 responding mills. Breakdown of the number of graduate chemical engineers by category of mill is shown in Table A.

It is estimated that about 72% of total U. S. production of pulp and paper is represented by this survey, not including the production of the 26 unidentified mills. An interesting point is that 20% of the mills reporting showed no graduate chemical engineers employed. However, the production so represented is only 6% of the total indicated for the survey.

As might have been expected, more graduate chemical engineers per mill (or per unit annual production) are employed by the pulp mills and the integrated pulp and paper mills than by the paper mills, per se.

Work is continuing on the remaining phases of the TAPPI educational program, and further reports may be expected in the near future.

A.I.Ch.E. building fund drive continues

Despite the fact that A.I.Ch.E., alone among the societies participating in the Member Gifts Campaign for the United Engineering Center, has more than fulfilled its quota, it is continuing its campaign. Present subscriptions to the Member Gift Campaign from all societies total \$2,552,394—overall quota remaining is \$1,244,000.

Major maleic anhydride plant for West Coast

Twenty million pounds of annual capacity for maleic anhydride will be erected at Richmond, California, by California Chemical, Standard Oil of California subsidiary. Completion is slated for mid-1960.

New Cyanamid subsidiary in Italy

Cyanamid Italia, newly-formed Cyanamid subsidiary in Italy, will be formed by purchasing assets of Azienda Laboratori Farmaceutici, SpA (Alfar), including an operating pharmaceutical plant in Catania, Sicily. Total investment involved is around \$4.8 million, seventy percent of which will be held by Cyanamid, the rest by Italian interests.

High-energy fuel research continues

Recent cancellation of Air Force and Navy contracts for operation of boron fuels production plants has not affected contracts between the Air Force and Stauffer-Aerojet Chemical for development of low-cost boron fuels, says Stauffer-Aerojet. Start-up of a large-scale pilot plant at Sacremento, California, is expected within a few weeks.

Boost urged in Army chemical research

A rise to about $125 million per year in the outlay for research under the Army Chemical Corps was urged recently by the House Committee on Science and Astronautics. This sum would represent about three times the amount provided for in the present budget.

Breaking with a long-established policy of almost complete secrecy in regard to chemical and biological warfare, the committee made public a report based on statements by top military officials. Behind the unprecedented action of the committee is believed to lie a fear that unless the general public is made aware of the dangers and problems involved in this type of warfare, the United States might well fall behind the Soviet Union in the development of this kind of military capacity.

In addition to pressing for increased research spending by the Army Chemical Corps, the committee called for more vigilant watching of foreign developments in chemical, biological, and radiological warfare, and inclusion of such matters in international disarmament discussions.

Interest in the committee report centers on a discussion of the newly-discovered "psychochemicals" or "incapacitents." These are said to be divided into two groups. The first group includes chemical agents which produce such temporary physical disabilities as paralysis, blindness, or deafness. The second group consists of agents which produce various degrees of "temporary mental aberations." According to the report, "unlike lethal war gases or the more virulent biological agents, the incapacitents can produce purely temporary effects without permanent damage." A film showed to the committee is said to have shown troops which had been exposed to one of the newly-developed incapacitents. The men "were not even conscious of their abnormal condition which was so changed that they were unable to follow simple commands and perform normal tasks with acceptable accuracy."

Experimental work in this field is said to be promising, but to be still in its early stages. No details are available as to the chemical constitution of the new agents.

Controlled fusion reaction?

"There is already a good deal of experimental evidence to support the belief that one (a controlled thermonuclear reaction) has been achieved," said recently a spokesman for the Naval Research Laboratory, referring to recent work financed jointly by the Navy and the AEC.

Hands across the sea

A new merger involves Hess Products Limited, London, England, and the Chemical Division of Armour Chemical Industries Limited. The new company will be known as Armour Hess Chemicals Limited, will be jointly owned by the two parent companies on a fifty-fifty basis. Hess Products was formed in 1946, when it acquired patent rights from Armour for fractional distillation of fatty acids.

Mexican titanium dioxide

A newly-formed Mexican company, Pigmentos y Productos Quimicos, capitalized at 51 million pesos, will operate a titanium dioxide plant now under construction in Tampico, Mexican Gulf seaport. Controlling interest in the enterprise is held by the Banco de Comercio, with Du Pont holding the balance of the common stock. Dupont will furnish technical know-how, and will assist in training technicians to operate the plant.

First Euratom—U. S. contracts

Awards, first to be made under the U. S.-Euratom Joint Research and Development Board are: American Standard Corp.—clad ceramic plate fuel elements by spray coating techniques; Battelle Institute—boiling heat transfer and void distribution on studies with water coolants; Compagnie Industrielle des Ceramiques Electroniques (France)—study of the extrusion of uranium oxide.

For more information, turn to Data Service card, circle No. 49

 Prepared by U. S. Industrial Chemicals Co.

U.S.I. CHEMICAL NEWS

September ★ A Series for Chemists and Executives of the Solvents and Chemical Consuming Industries ★ 1959

New Sodium Hydride Analysis Developed

A new and unconventional method of analyzing sodium hydride for contained sodium hydride and residual sodium was developed recently at the U.S.I. research laboratories.

The determination of completeness of reaction between sodium and hydrogen to form the hydride presents a problem because of the reactivity of the latter with air and moisture. Sampling is difficult and conventional analytical procedures are inadequate since both sodium and sodium hydride yield hydrogen and caustic when treated with water.

The method developed by U.S.I., however, is actually based on the differential amounts of hydrogen and caustic formed when sodium hydride containing small amounts of sodium is treated with water in a decomposition flask.

The sample need not be weighed if only the relative amounts of sodium and sodium hydride are desired. Accuracy depends on rigorous sampling, and the best method involves the use of a small 10cc. hypodermic syringe.

Weight of sample can be obtained, if desired, by weighing the syringe (with material being analyzed) before and after introducing the sample into the decomposition flask.

A data sheet giving complete details on this method of analysis and a diagram of the apparatus can be obtained from U.S.I. upon request. Production of sodium hydride from dispersed sodium is outlined in U.S.I. Sodium Dispersions brochure, also available on request.

New Zirconium-Copper Alloy Now on Market

A recently developed zirconium-copper alloy, said to possess excellent electrical conductivity and high-temperature strength properties, is expected to find many applications in the electrical field. The new alloy consists of high-conductivity, oxygen-free copper and carefully controlled concentrations of high-purity zirconium.

It is distinguished by the high strength level it develops through cold working and the extent to which it retains this strength at elevated temperatures. A typical bar of the alloy, cold-worked 60% and aged for one hour at 400°C, exhibits the following: tensile strength, 63,000 psi; yield strength, 59,000 psi; elongation, 12%, electrical conductivity, 90-95%. At 400°C, the short time tensile strength is 46,500 psi. Additional cold-working will increase the strength of the alloy without sacrificing ductility and electrical conductivity. Endurance tests show it to be far superior to unalloyed copper.

The high softening temperature of the alloy permits welding, brazing, silver soldering. Silver plating is also practical with only minor modifications in procedures. Billets cast with the new alloy are reported to be free of inclusions and flaws — hence have better hot and cold workability.

First Interim Regulations On Tax-Free and SD Alcohols Implement 1958 "Changes" Act

Continuing Industrial Use Permit Is One of Major Changes.

The first interim regulations written to implement the Excise Tax Technical Changes Act of 1958 (Public Law 85-859, 72 Stat. 1313), which went into effect July 1 this year, were published in the Federal Register of June 12. These regulations provide for administration of the Internal Revenue Code of 1954 as amended by the "Changes" Act, and will be effective until superseded by permanent regulations.

The following changes are significant for users of pure and specially denatured ethyl alcohols:

(1) *Industrial Use Permits* — permits to use SD Alcohol, Form 1481 and Tax-Free Alcohol, Form 1447, issued effective on or after July 1, *are continuing* (unless terminated by the terms thereof, suspended, revoked or voluntarily surrendered). It was formerly necessary that these permits be renewed each year.

(2) *Withdrawal Permits* — issued on or after July 1 *expire* as follows: SD Alcohol, Form 1485, expires October 31, 1960; Tax-Free Alcohol, Form 1450, expires April 30, 1961. It was formerly necessary to obtain new permits each year.

(3) *Use of Tax-Free Alcohol* has been extended to include blood banks, educational organizations exempt from federal income tax, pathological laboratories with certain restrictions. The blood banks were not previously specified. The restrictions of use by various institutions have been clarified.

MORE

What's Cooking? World's first all-titanium frying pan is being used here by Jean Gregoire, executive chef of New York's Hotel Roosevelt, to fry eggs for hungry patrons. The experimental pan was fabricated by Mallory-Sharon Metals Corporation, Niles, Ohio (one-third owned by U.S.I.), as part of a nationwide program to promote uses for the light, strong, corrosion-resistant metal.

Ethanol Widely Used in Pharmaceutical Aerosols

Medicine in aerosol form, for therapy by inhalation, has gained considerable acceptance in the last few years. There is much well-documented clinical evidence for the suitability of aerosols in the treatment of asthma, for example. And as new aerosol formulations are developed and tested clinically, it is expected that this form of inhalation therapy will be used even more widely in the future.

Judging from a group of typical formulations published recently by *Drug and Cosmetic Industry Magazine*, ethyl alcohol is an essential ingredient in this type of pharmaceutical aerosol. Examples of bronchodilator amine

MORE

AEC OKs Operation at Full Power for World's Largest Private Research Reactor

The largest independent industrial research reactor in the world is now being operated by Industrial Reactor Laboratories, Inc. at Plainsboro, N. J., for U.S.I. and nine other companies. After extensive safety tests, the Atomic Energy Commission recently authorized operation of the reactor at its full design power level of 5,000 kilowatts (thermal).

Previously the facility had been granted authority to operate at power levels not exceeding 100 kilowatts during tests which included stringent safety studies. Upon completing these tests, the AEC supplemented its amendment to IRL's license. It now states that, in the opinion of the Commission's hazards evaluation branch, the reactor can be operated at the five megawatts rate without undue hazard to the health and safety of the public.

September ★ U.S.I. CHEMICAL NEWS ★ 1959

CONTINUED Alcohol Regulations

(4) *Samples* — proprietors may now furnish without permits samples of SD Alcohol of one quart to users, applicants or prospective applicants for permits (for experimental purposes or preparation of samples to be submitted to the Director). Previously only samples up to eight ounces could be furnished without permits.

(5) *Carrier Permits* — permits are no longer required to transport tax-free, specially denatured and undenatured alcohol, including tax-free distilled spirits.

As further interim regulations are published, U.S.I. will endeavor to keep industrial alcohol users informed as to the important changes.

CONTINUED Aerosols

formulations included one containing:

Isoproteronol HCl	0.20%
Water	2.00%
Ethanol (absolute)	37.80%
Propellants	60.00%

Typical cardiovascular drug formulations included the following:

Nicotine	1.00%
Ethanol 95%	34.00%
Propellants	65.00%

And an antispasmotic formulation given contained:

Atropine	0.1%
Ethanol 95%	9.9%
Propellants	90.0%

U.S.I. Appoints New Sales Manager for Detroit Office

On September 30th, Fred M. Henley retires as Manager of the U.S.I. Detroit Sales Division, after a long and successful career with the company. Succeeding Mr. Henley is Walter J. Kilmer, who has been associated with U.S.I. for 25 years as a sales representative for the company in the Buffalo, N. Y., area.

W. J. KILMER

U.S.I. at the International Plastics Show

U.S.I.'s booth at the International Plastics Exhibition was the background for the opening ceremony, June 17th, in Grand Hall, Olympia, London.

TECHNICAL DEVELOPMENTS

Information about manufacturers of these items may be obtained by writing U.S.I.

New cleaning agent claimed to combine functions of solvent and detergent can now be obtained. Has low volatility, no flashpoint. Forms clear solutions with water, all chlorinated solvents, most safety solvents. **No. 1510**

New periodical on biochemical and biophysical research now being published and sold. Said to meet need for rapid dissemination of information in experimental biology. Information appears as short, well-documented communications. **No. 1511**

Water-soluble anti-caking agent said to be effective in concentrations as low as 0.025-0.05%, is now on market. Material is organic, practically salt-free. Available as 90% powder and 50% free-flowing liquid. **No. 1512**

Simple slide rule for polyethylene film and bag measurements has been developed. Permits rapid determination of width, length, total area, weight, gauge in one setting of the rule, with only one or two constants known. **No. 1513**

Diethylaminoethyl phenylethyl acetate citrate has been found, in new research, to exhibit stronger, faster broncho-dilating action than ephedrin. Cough reflex is stopped more effectively than by codeine. **No. 1514**

Chemistry of drugs is covered in new book now being sold. Both synthetic and natural drugs are discussed as to structure, preparation and synthesis, properties, uses. A table gives approved, chemical and proprietary names. **No. 1515**

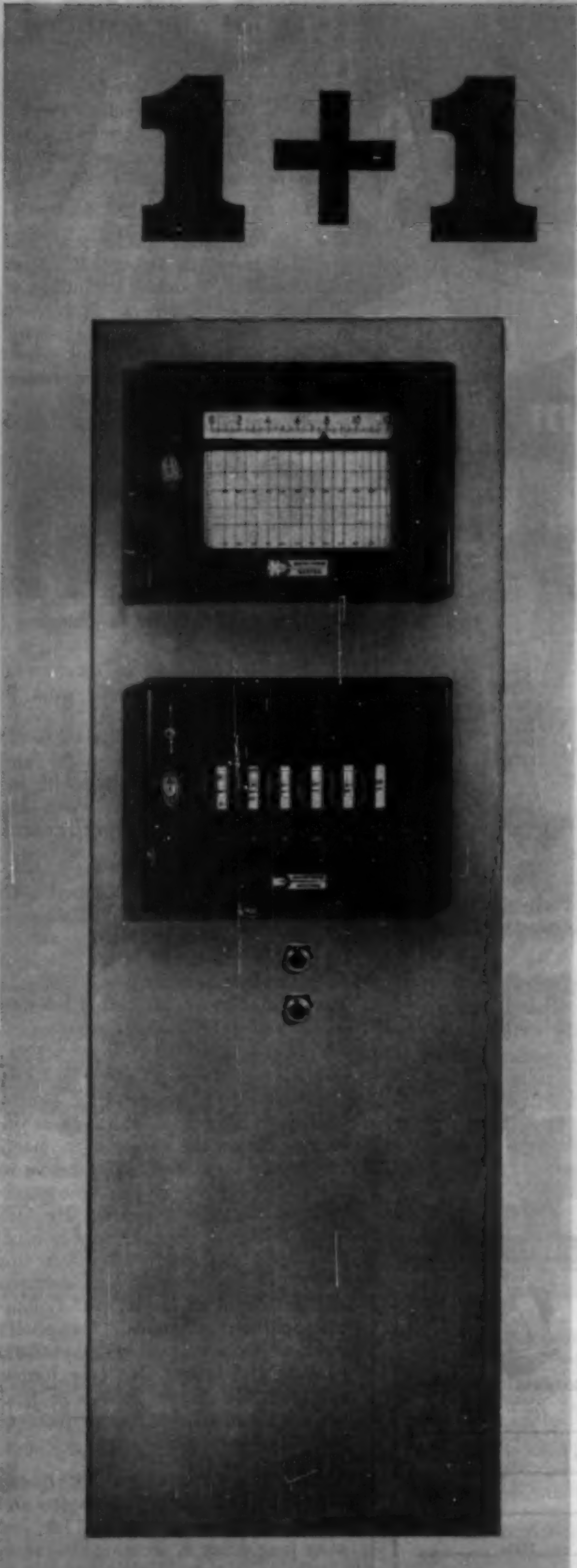
New fatty-nitrogen-derived corrosion inhibitor has been developed for use in 5, 10, 15% HCl over a wide temperature range. Claimed to control corrosion on metals such as stainless steels 316 and 420, monel, bronze, mild steel. **No. 1516**

Objective measurement of odor is said to have been achieved by techniques which use the latest in ionization detector gas chromatography equipment. Permits correlation between subjective and objective odor evaluation. **No. 1517**

First chewable iron tablet for children has been introduced. Contains ferrous fumarate and vitamin C and will not stain teeth, according to manufacturer. Intended for oral treatment of iron deficiency anemia. **No. 1518**

All-polyethylene chemical pump for dispensing from drums, carboys, etc. can now be obtained. Said to operate with ease and wear-free smoothness, due to special valve design. Furnished with drum-bung adapter. **No. 1519**

1+1=6



CORRECT!

Maybe not in second grade, but correct with this new Daystrom-Weston economy "package": the Model 6134 Multi-Point Controller and Model 6702 Multi-Point Recorder combination.

Up to six individual recording controllers can now be replaced by this two-unit set-up.

Up to 50% in cost reductions can be realized over individual units when 6 points are specified for each instrument. As many as 18 additional points can be added to the recording unit if desired.

Savings are not limited to initial cost alone. Compactness, flexibility and accurate, reliable operation free from maintenance worries all contribute to substantial long-range savings as well.

Both independent units employ the exclusive D-PAK® Constant Current Source, eliminating many conventional components such as batteries . . . standard cells . . . standardizing mechanisms. Their unitized design makes for easy accessibility of interior parts . . . provides precise 2- or 3-position electric contact control.

Two distinctly separate circuits afford dual protection against overtemperature. Alarm circuits set for individual points in the Recorder provide high or low temperature cut-off as desired. Two separate or one common thermocouple can be used for each point – as the installation demands.

Control packages, including panels and accessories, can be suited to your own specific application.

For further information, contact your local Weston representative . . . or write to Daystrom-Weston Sales Division, Newark 12, N. J. In Canada: Daystrom Ltd., 840 Caledonia Rd., Toronto 19, Ont. Export: Daystrom Int'l., 100 Empire St., Newark 12, N. J.

DAYSTROM
WESTON

World leader in measurement and control

DAYSTROM-WESTON INDUSTRIAL INSTRUMENTS include a full line of recording and controlling potentiometers with strip and circular charts; mechanical recorders and indicators for pressure, temperature and flow; and non-indicating controllers, both electric and pneumatic.

For more information, turn to Data Service card, circle No. 76

about our authors

Ralph A. Morgen, director, Purdue Research Foundation, continues his report on *Chemical Engineering Education in the USSR* in this month's issue.

The field of fluid mechanics is of special interest to **George E. Alves** and **Donald F. Boucher**, co-authors of *Dimensionless Numbers*. Both men are connected with the engineering research laboratory at Du Pont. Alves, who joined the company as a chemical engineer in 1946, is at present a research supervisor. He has a degree in chemistry, an MS in mechanical engineering, and has done work in supersonic aerodynamics.

Alves Boucher Bebbington

Boucher has two additional areas of specialization, heat transfer and polymer manufacture, along with his work in fluid dynamics. With Du Pont for 19 years, he is now research manager in the laboratory.

Paul M. Lindstedt, Kenneth G. Roquemore and **Everett W. Campbell** (*Pilot Plant Product Quality*) are all on the executive staff of the chemical engineering laboratories at Goodyear Tire & Rubber, Akron, Ohio. Lindstedt is manager, chemical development; Roquemore and Campbell are section heads.

Lindstedt, a veteran of twenty years with the company, has spent the entire time on the chemical engineering development staff. Long active in A.I.Ch.E., he was at one time president of the Akron Section. He also headed the Akron Council Scientific Societies. Roquemore worked for several years, until 1951, as research and development engineer at Columbia Southern Chemical. Campbell's work at Goodyear is with synthetic rubbers and latices. He is a former officer in the Akron Section of A.I.-Ch.E., having held the position of secretary.

The article, *Production of Heavy Water*, by **William P. Bebbington** and **Victor R. Thayer**, appears at last after long delay in securing clearance.

continued on page 24

about our authors

from page 22

Information contained in the paper was developed as a result of work done under Du Pont's contract with AEC.

Bebbington is with Du Pont's Atomic Energy Division, Aiken, South Carolina. Thayer is director, chemical process section, in the same company division at the Wilmington, Delaware, plant.

Allen F. Sherzer (*Net Positive Suction Head*) has had a long and varied career, both in the business and academic worlds. It includes a total

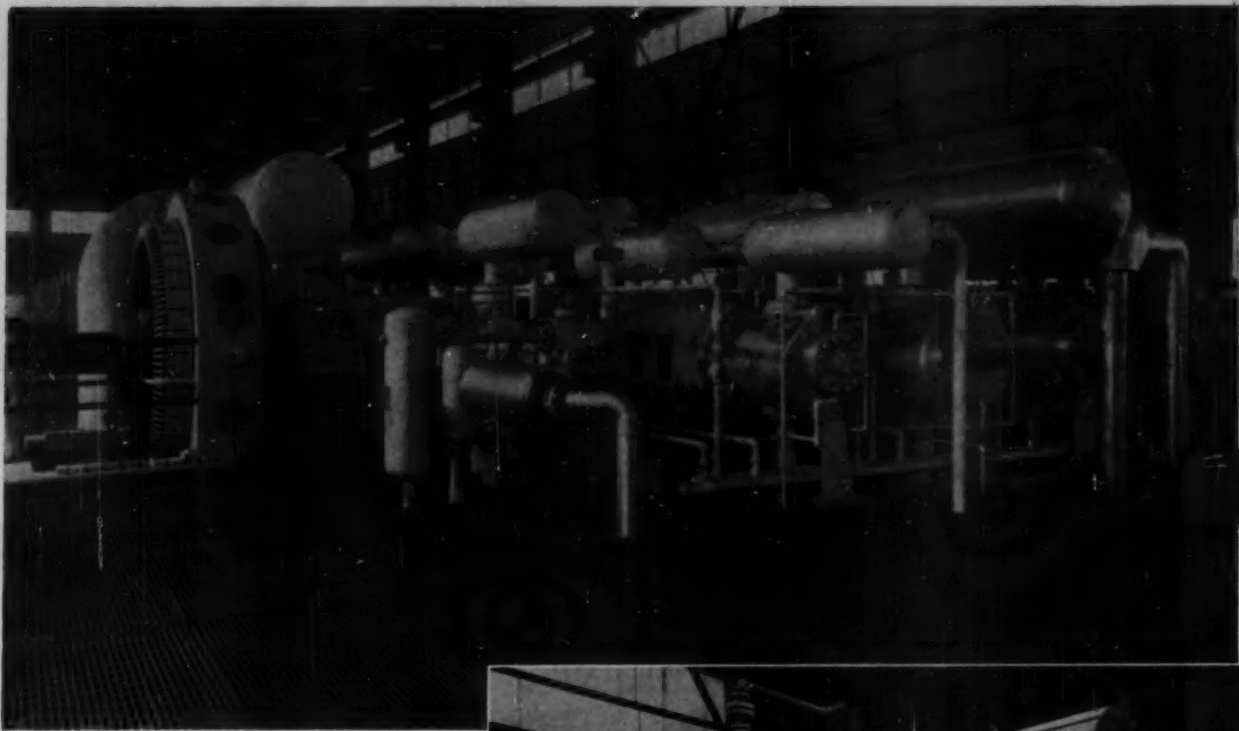
Lindstedt Campbell Thayer

of twenty-six years as instructor on the faculty of the University of Michigan, and several years at Kingsford Foundry in charge of the Pump and Engine Department. Sherzer at present heads his own firm, Sherzer Pumps. The Ann Arbor, Michigan company manufactures centrifugal pumps for the chemical industry.

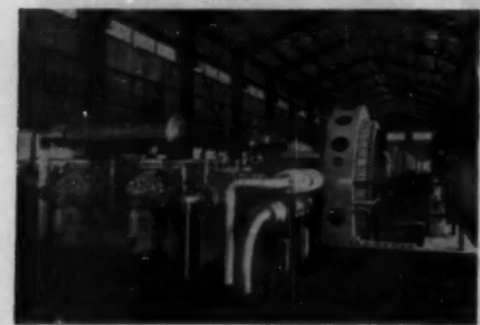
(*Process Evaluation*) is the result of collaboration between four members of American Cyanamid's Engineering and Construction Division in New York City. **R. F. West** is responsible for chemical process design at the company's Santa Rosa plant for Creslan fiber. He got his doctorate as a Du Pont Fellow at Columbia University, and joined the company in 1951. He is currently senior process engineer. Another Columbia alumnus, **J. S. Hegedus** joined the firm right

McIntire Yuan West

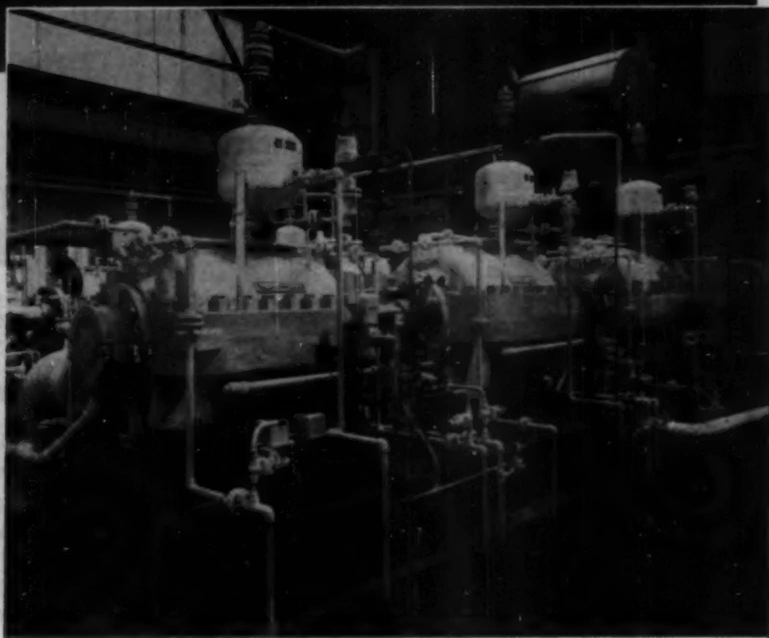
from school, as did **L. L. Yuan** who got his Ph D from Illinois Institute of Technology. **W. C. McIntire** has had 27 years with American Cyanamid. His background includes experience in developing, controlling, evaluating and scaling up processes for manufacture of pigments, organic chemicals, and intermediates.



▲ Two 3500-hp HHE compressors in P.C.I. ammonia synthesis plant. Each 12-cylinder unit simultaneously compresses air and nitrogen, each in three stages; ethylene and high-pressure nitrogen, each in two stages; and low-pressure and high-pressure ammonia gas services, each single-stage.



▲ Two 3000-hp HHE hydrogen source gas compressors, each handling waste gases from Platformer, Hydroformer and butadiene plants, as well as ethane and methane residual gases, in eight separate compressor cylinders.



▲ Train of three multi-stage horizontally-split centrifugal units compressing ethylene gas to 396 psi.

◀ Two 4000-hp HHE's compressing ammonia synthesis gas in four stages to 9255 psi.

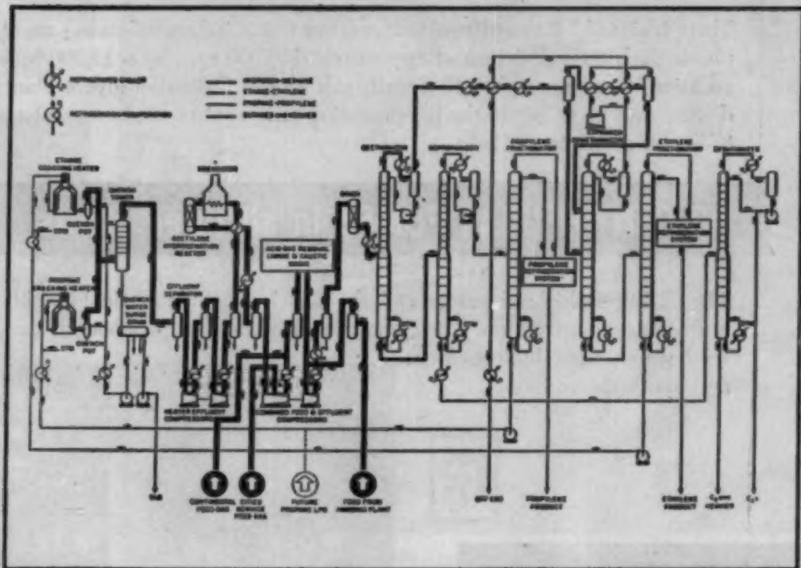
▶ Train of four multi-stage horizontally-split centrifugals with gas-turbine drive, compressing 10,750 cfm of hydrocarbon feed gas to 525 psi at the P.C.I. ethylene plant.

LUMMUS

ENGINEERS AND CONSTRUCTORS FOR INDUSTRY

NEW ETHYLENE PROCESS DEVELOPED BY LUMMUS PROVIDES HIGH EFFICIENCY UNUSUAL FEED-STOCK FLEXIBILITY

200,000,000 Lb/Year Plant for Petroleum Chemicals, Inc. Produces 99.7% Ethylene



The new Petroleum Chemicals, Inc. ethylene plant, now on stream at Lake Charles, Louisiana, incorporates a unique ethylene separation process developed by Lummus which provides high separation efficiencies and unusual flexibility and reliability (See flowsheet).

Lummus has designed the plant for rapid 50% expansion to a rate of 300,000,000 lbs/year. Ethylene is produced in two grades — the highest, 99.7%; the other, 98%. Coproducts are high purity propylene, a butane-butylene fraction and aromatic distillate. Operations have been marked by continuous production of specification ethylene under widely varying rates and feed stock compositions.

Feed Gases From Three Sources

Feed gases for the P.C.I. plant are provided from three different sources: the nearby refineries of Cities Service and Continental Oil—by whom P.C.I. is jointly owned—and P.C.I.'s new ammonia plant.

High Efficiency Expanders

All major compressors in the Lummus-designed low temperature fractionation unit are driven by three 12,500 HP gas turbines. Gas turbine exhaust serves as preheated air for three high pressure steam generators. High efficiency expanders provide low temperatures for maximum ethylene recovery.

Ethylene is delivered via pipeline to customers at Orange, Texas. In addition, part of the new plant's output feeds the adjacent Calcasieu Chemical Corporation ethylene oxide and glycol plant, also engineered and constructed by Lummus.

This plant brings the total of Lummus-designed ethylene plants to 13, with a combined capacity of over 1 billion pounds per year: (contd. next page)

CUSTOMER	LOCATION
Monsanto Chemical Co.	Texas City, Texas, U.S.A.
Jefferson Chemical Co.	Port Neches, Texas, U.S.A.
E. I. du Pont de Nemours & Co.	Orange, Texas, U.S.A.
Texas Eastman Co.	Longview, Texas, U.S.A.
Gulf Oil Corp.	Port Arthur, Texas, U.S.A.
Societe Naphtachimie S.A.	L'Avera, France
Allied Chemicals Corp.	Tonawanda, New York, U.S.A.
National Petrochemicals Corp.	Tuscola, Illinois, U.S.A.
Canadian Industries, Ltd. (2 plants)	Edmonton, Alberta, Canada
Polymer Corporation Ltd.	Sarnia, Ontario, Canada
Societa Edison	Mantova, Italy
Petroleum Chemicals, Inc.	Lake Charles, La., U.S.A.

New Ethylene Oxide-Glycol Plant is third Shell process unit engineered and built by Lummus

Calcasieu Chemical Corporation's new ethylene oxide-glycol plant at Lake Charles, Louisiana is on stream and producing 8,000,000 gallons annually of ethylene glycol or 57,000,000 pounds of ethylene oxide.

Designed and engineered by The Lummus Company, the plant utilizes the two-step Shell Development Company Process, which offers the advantages of unusually high yields and virtual elimination of the waste-disposal problems encountered in the Chlorohydrin Process. The first step is direct catalytic oxidation of ethylene with oxygen in fixed bed reactors. Here ethylene oxide, valuable petrochemical intermediate, is produced for use by manufacturers of detergents and other surface active agents, plasticizers, solvents, textiles, drugs and many other petrochemical compounds.

The second step of the Shell Process calls for thermal hydration of ethylene oxide to ethylene glycol, essential to manufacturers of antifreeze, explosives, plasticizers, fibers, resins, hydraulic fluids and many more chemical products.

Article tells when to contract for pilot plant work, when to 'do it yourself'

Reprints are available now of a four-page article which discusses factors to consider in deciding when to engage an outside firm to do pilot plant work and when to "do it yourself." The article includes a comparative analysis of costs on a specific project: (a) as actually completed by Lummus for a client and (b) if the client had undertaken the program himself. For copies, write Lummus.

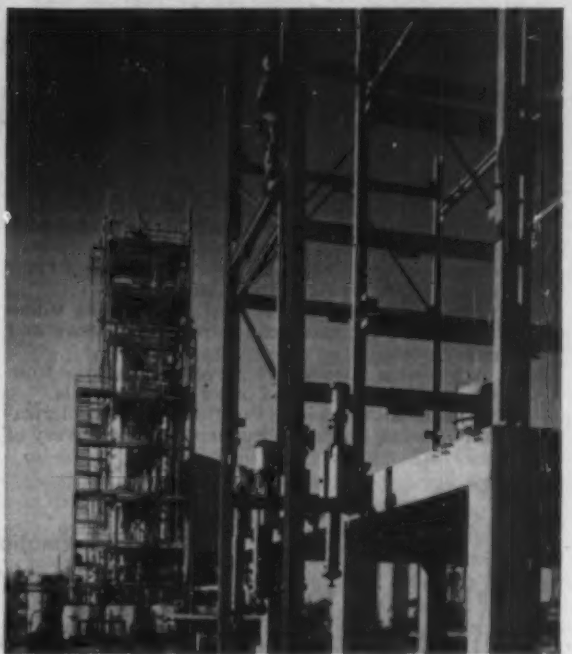
Over a half-century of Process-Industry experience

Here is just a partial list of chemicals for which Lummus has designed, engineered or constructed plants:

Acetone	Dichlorethane	Nitric Acid
Acrolein	Dichlorobenzene	Phenol
Allethrin	Di-isobutyl alcohol	Phthalic anhydride
Ammonia	Ethylbenzene	Polyvinyl alcohol
Ammonium Nitrate	Ethyl Chloride	Polyvinyl Pyrrolidone
Ammonium Sulfate	Ethylene	Propargyl Alcohol
Benzol	Ethylene glycol	Propylene
Beryllium metal	Ethylene oxide	Pyrrolidone
Bisphenol	Epon® resin	Styrene
Butadiene	Formaldehyde	Sulfuric acid
Butanediol	Heavy Water	Surfactants
Butynediol	Hydrogen	Tetramer
Butyrolactone	Hydrogen Sulfide	Trichlorethylene
Carbon black	Isopropyl alcohol	Trichlorobenzene
Caustic soda	Lamp black	Toluene
Chlorobenzene	Magnesium sulfate	Uranium Oxide
Cumene	Mercuric nitrate	Vinyl acetate
Di-ammonium phosphate	Naphthalene	Vinyl Pyrrolidone

Discuss your next chemical or petrochemical project with a Lummus representative.

THE LUMMUS COMPANY, 385 Madison Avenue, New York 17, N. Y., Houston, Washington, D.C., Montreal, London, Paris, The Hague, Maracaibo. Engineering Development Center: Newark, N.J.



MORE POLYVINYL ALCOHOL RESIN — 20 million pounds per year — will come from Air Reduction's new installation in Calvert City, Kentucky, now being engineered and built by Lummus. Shown above are Airco's original vinyl acetate monomer plant and the beginning of the new monomer plant which will double vinyl acetate output. The twin monomer plants will be the core of the huge polyvinyl alcohol resin operation, scheduled to come on stream early next year.

For more information, turn to Data Service card, circle No. 133

When your new plant goes "on stream"...

...benefit from the proven advantages of a PITTSBURGH GRANULAR ACTIVATED CARBON Adsorption System!

Are you planning new processing facilities for liquid or vapor phase adsorption? If so, you should be acquainted with the unique and *proven* advantages of a continuous column system using PITTSBURGH Granular Activated Carbons.

Here are just a few typical applications where such a unit operation can improve efficiency and reduce costs:

1. Incoming Materials: Removal of impurities from process water, gases and other raw materials.

2. Materials in Process: Purification or decolorization of prime products. Purification or recovery of valuable solvents used repeatedly in recirculating streams. Catalysis and catalytic support.

3. Plant Effluents: Treatment of waste gases and liquids to recover valuable constituents or to eliminate pollution problems.

If you're planning new or improved adsorption facilities at your plant, it will pay you to talk to a PITTSBURGH Technical Representative. He has helpful engineering data and case history studies which demonstrate how you can benefit by the use of PITTSBURGH Granular Carbons in a continuous column system.

Want More Information? Send for This Booklet

Describes various types of liquid and vapor phase adsorption operations . . . and types of Pittsburgh Granular Carbons best suited for each one. Send for your free copy. Write to Dept. R.

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Acetylene developments—Know-how to USSR

Acetylene-based plastic film, claimed several times as strong as polyethylene, may make big inroads in the plastic film market in the next few years, believes Dupont, about to start large-scale production of "Teslar." Price is thought to be the one main hurdle to be jumped in commercial exploitation of the new product. Introductory price is expected to be in the neighborhood of some $5 a pound, relatively expensive when compared to today's present market price for polyethylene film—about 35¢ a pound. However, certain advantages of Teslar may outweigh price considerations for some applications. It is claimed to be almost completely resistant to sunlight which could make it an ideal roofing material. It can be made, says Dupont, in thicknesses down to one two-thousandth of an inch.

Polypyrrolidone fiber, under development at General Aniline, is another acetylene product which may, in time, give nylon a run for its money. Expected to be in the same price range as nylon, the new fiber is said to be easier to dye and, particularly important for textile uses, to have less tendency to soil and to cling to the skin.

A third horse in the race is a new polyvinyl alcohol film being made by Bordon Chemicals. Chief claim to fame for Bordon's entry is that, while it will resist heat, it dissolves in water. It is understood that a logical application under consideration is the packaging of detergents for the retail market. The detergent would be put up into small wash-size packages which would dissolve in the washing machine. Present cost of this polyvinyl film is quoted at about $2 a pound.

With these and other new uses for acetylene coming forth every day, some industry sources are looking for a three-fold rise in acetylene consumption during the next ten years. That this estimate may well be realistic is indicated by the fact that, while sales of acetylene for use in the chemical industry were only $45 million in 1956, by 1958 they had risen to about $75 million.

Soviet trade

In a surprise move, the Soviet Foreign Trade Authority "Techmashimport" has signed a contract with Montecatini of Milan, Italy, according to the terms of which Montecatini will furnish to the Soviet processes for production of maleic anhydride, titanium dioxide, acetylene, and ethylene. It is understood that a tie-in deal provides for supply of much of the necessary process equipment for the plants by Italian equipment fabricators. This agreement follows several of the kind reported to have been negotiated with the Soviets by other European chemical companies. In the U.S., the chemical industry, spearheaded by the Manufacturing Chemists Association, has taken a strong stand against the sale of chemical process know-how behind the Iron Curtain.

On the other hand, according to a report by the *Wall Street Journal*, licenses for export of goods from the U.S. to Russia are up "sharply" in the second quarter of this year. Interestingly enough, certain of these exports were either chemicals or other commodities useful in their manufacture. The Commerce Department, says the *Wall Street Journal*, approved in the second quarter licenses for export to Russia of $1,171,000 worth of paper pulp machinery and $750,000 worth of butyl alcohol. The total of licenses issued during the second quarter, according to the report, was about $3,300,000, compared to only $376,000 approved during the first three months of the year.

SILICONE NEWS from Dow Corning

Knock-Out Drops For Foam!

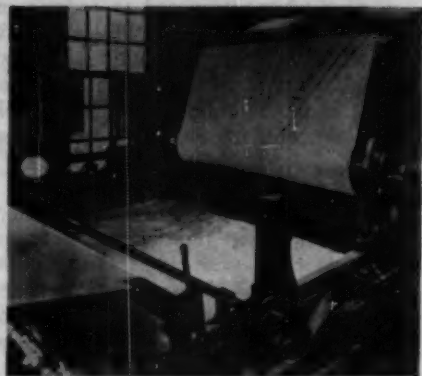
Control Foam in Any Type of System with Low Cost Silicone Defoamers

Does foam occur in your process operations? Chances are you can keep it under control at all times with a Dow Corning silicone defoamer. Job-proved in virtually every industry . . . petrochemical, textile, paper, paint, food and many others . . . Dow Corning silicone defoamers knock down the most violent and persistent foam. Eliminate processing slow-downs and boil-overs. Reduce fire hazards. Cut waste and clean-up costs.

AVAILABLE IN HANDY SPRAY CAN

And Dow Corning silicone defoamers are amazingly effective in minute quantities. For example, just 1 ounce of a Dow Corning silicone defoamer prevents foam in 31,250 pounds of dog shampoo, in 59,110 pounds of wire drawing solution, and in 62,500 pounds of paper coating solution . . . are similarly effective in defoaming adhesives, latices, caustic liquor, soap, varnish, emulsion paints and coatings, cutting oils, petrochemicals, food products . . . many, many others.

Dow Corning's continuing research study of foam and its control has brought about the availability of silicone defoamers as compounds and emulsions for different types of production systems — and in handy spray cans for split-second defoaming of smaller batch processes. Settle your foam problems once and for all time with a Dow Corning silicone defoamer. A generous trial sample is yours for the asking. Indicate your problem and system — oil, aqueous, nonaqueous, food product, or any other. Write Dept. 2321 for a rapid reply.



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For more information, turn to Data Service card, circle No. 9

opinion and comment

How much is a man worth?

"An institution is but the lengthened shadow of a man" is an ancient testament to the importance of the individual.

The modern corporation, so dependent upon managers, obviously recognizes the importance of a man, for much that it does is based on finding the right man for the right job at the right time. Schools of business administration, specialists in management development, management seminars, psychological evaluations, all are aimed at creating administrators and managers.

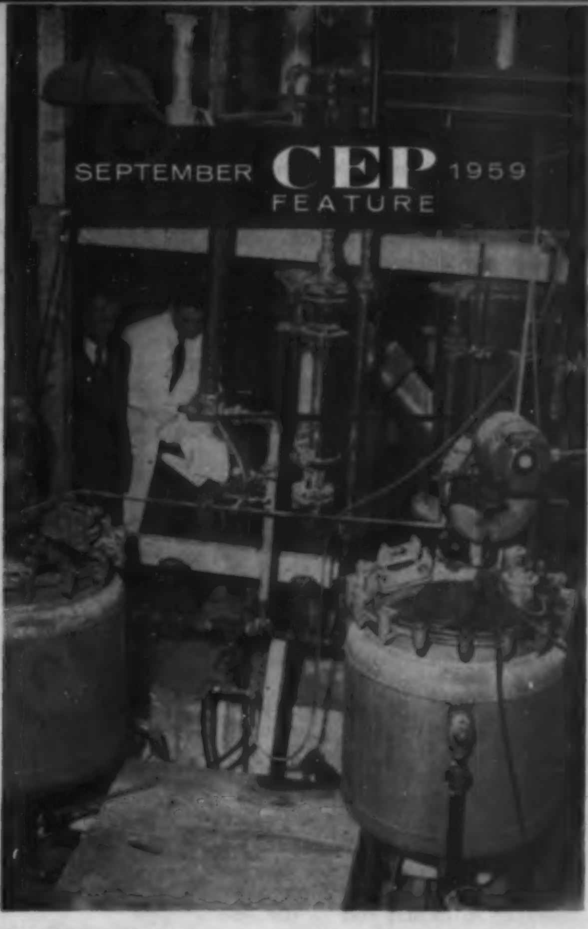
It sometimes seems, however, that not quite enough energy and attention are paid to finding and developing the engineer. The function of administration is to make decisions based on engineering costs and market data presented by specialists. Administrative evaluation does not rest on the accuracy of the technical details of the report—that is taken for granted—but upon the commercial chances of success, the commitment of the corporation in other fields, and the whole financial picture. The decision is not really to produce a certain chemical by a certain process—that has already been worked out by the engineer. The administrator's decision is to spend money. More and more, as administration becomes dependent upon the decisions of its engineering managers, it must be selective about engineers. In engineering, too, we need the right man in the right job at the right time.

Just recently an engineer explained to us how through the efforts of himself and his design group he had managed to make certain engineering process changes that saved his corporation some twenty thousand dollars a month in steam alone. What is such a man worth to a corporation?

Again, at the recent Storrs Heat Transfer Conference, we were struck by the number of references in the papers and in conversation to Allan Colburn, for whom we have just renamed the Junior Award, which recognizes excellence in the chemical engineering papers of younger members. One of the engineers who knew Colburn testified to his remarkable ability to grasp the whole problem from a few isolated data and to propose a correct solution. The time, energy, and money that Allan Colburn's theoretical studies have saved the chemical process industries can never be calculated. He was the right man at the right time in the right place. What would we not give to develop myriad engineers such as he!

As we face the problems of internationally competitive engineering for the years ahead, the problems of technology for the space age, we are concerned not so much with the supply of engineers as with the supply of well-qualified engineers. Quality of education is not the factor. Recent studies showed that the two strongest points of newly graduated chemical engineers were (1) their mastery of their technical subject and (2) their entire professional attitude toward their work and their calling. This is a remarkable educational achievement, and it is up to management to build carefully on this foundation. Developing engineers is an important aspect of corporate management. This does not mean only that they should be well paid, although this, of course, is extremely important. It means seeing that they, too, have their opportunity at management schools, that they have their share of fringe benefits, extra vacations, adequate stenographic help, company stock plans, and company recognition. It means seeing to it that these men have the latest and most efficient tools for their technical work, the opportunity to publish findings and to attend meetings, and time to think. The profit can be tremendous—the reward to a company that has an intelligent program for its engineering staff is the reward of being first in its field.

F. J. V. A.



Process evaluation

. . . Technical and economic factors in profitable process development

R. F. West, L. L. Yuan,
J. S. Hegedus, and W. C. McIntire
American Cyanamid Co.
New York 20, N. Y.

The prime responsibility of a process evaluation department is to determine the feasibility of commercialization of chemical processes, both as to practicability and economic yield. The process evaluation group performs this duty by providing management with a clear picture of the plant and its operation as it would probably be, based on currently available information.

Process development is a continuing activity. The evaluation group should be in contact with the research and development groups as soon as a decision to develop the process is made. The course and extent of the development work will be determined by the uncertainties and difficulties to be expected in the plant under study.

The process evaluation department usually consists of a nucleus of experienced process engineers who can readily appraise process data for adequacy, and project those data into hypothetical plants. In addition to providing the evaluation report, *per se*, the evaluation department can provide the process design department with preliminary process flow sheets and design data. In a staff capacity the evaluation engineer can assist the process design engineer in establishing the detailed design of the process. Evaluation of a process is equally applicable to process improvements or plant alterations.

To evaluate a process it is necessary that data be provided by the laboratory and pilot plant defining the operating conditions and yields to be expected. It is also necessary that additional data be supplied by the Market Research Department to establish the size of the market and the prices to be charged for the product or products under consideration.

Flow sheets, material balances, utility usages, and estimates of capital expenditures can then be established by the process evaluation department so that operating costs, probable profits, and payout time can be determined for the scale of manufacture being considered.

The accuracy of the evaluation will depend on the adequacy of the data available and on the optimum use of these data in establishing the best design and minimum cost of the proposed plant.

Sources of data for process evaluation

The required data are obtained from various sources.

Data from the laboratory. Information concerning chemical reactions involved, raw material and finished product specifications, physical and thermodynamic data, effects of proc-

14 pages of scale-up, pilot plant, and process development—more in Oct.

continued

ess variables, methods of isolation and purification, and process hazards may all be obtained from the laboratory.

Data from market research. The probable size and location of the market for a proposed new product should be established by the Market Research Department from their investigations of captive markets, competitive sales of similar products, and from customer reactions to the advantages of the new product. The size of the probable market will determine whether the future plant should be a new unit at a new site, or adjacent to an existent facility, or even only modification of equipment in part-time use.

Data from the pilot plant. Confirmation of yield and quality data, test data on unit operations, and results of corrosion tests may be obtained from the pilot plant.

Data from manufacturing department. A site survey should be made by the manufacturing department and the plant should be located where it can best be integrated with available services, with similar products, and with expected markets. Availability of services, tank farm storage, or raw materials may make an appreciable difference in capital cost of the off-site facilities.

Development of the evaluation design

All of the creative ability of the evaluation engineer is called into play in visualizing the hypothetical plant that would result from the available data. To this task, the engineer brings engineering judgment and his knowledge in correlation of data and application of the data to design. The hypothetical plant which gradually takes form in his imagination must be described in enough detail so that others can share his visualization and help determine the operating characteristics of the plant. The details of this description must not be so complete that undue expense of time and effort is incurred. For general purposes of evaluation, process flow sheets, material and energy balances, equipment lists and plot plans should be developed.

Evaluation of the process

Having designed a hypothetical plant, an evaluation must be made to determine whether or not the manufacture of the product will be economically attractive. The profitable investment of the funds at its disposal is the ultimate concern of management.

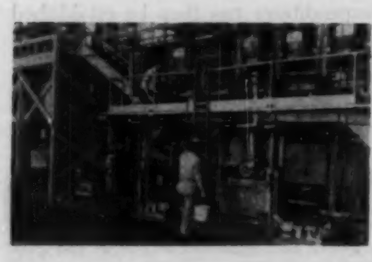
The profitability of a new chemical undertaking such as the building of a new plant, can be expressed in such terms as payout time, return on investment, and others. Payout time is a commonly used yardstick for measuring the profitability of potential manufacturing units. For its calculation, it is necessary to estimate the capital cost and the operating cost of the plant.

Capital cost estimates. The estimate is usually given as a range which reflects the accuracy of the information available to the estimator. Statistical evidence, accumulated in previous estimating work and applied successfully to estimating other major projects, has led to the establishing of a correlation between the extent of the information available to the estimator, and the accuracy of his estimate. Estimates of varying accuracy may be developed for various purposes; these may be called (in order of increasing accuracy) factored, study, scope, project control, and firm estimates.

The type most commonly employed in evaluation is the study estimate, with an accuracy range of 30%. The information required for a study estimate is not very extensive and can be developed in a relatively short time.

The accuracy of the capital cost estimate increases with completeness of information. Equipment lists developed for process evaluation are not like bills of material, which usually contain all of the items that make up a plant. The description of the equipment is, as a rule, limited to the identification of the item, its capacity, approximate dimensions, and the materials of construction.

The accuracy of the design itself is reflected in the estimate, although only indirectly. Lack of precision in equipment design is a necessary consequence of the lack of basic process information. Since the range of accuracy for any type of estimate is the result of a statistical survey which compares the deviation of actual cost from the estimated cost, the error inherent in the equipment design is automatically included in the overall error.

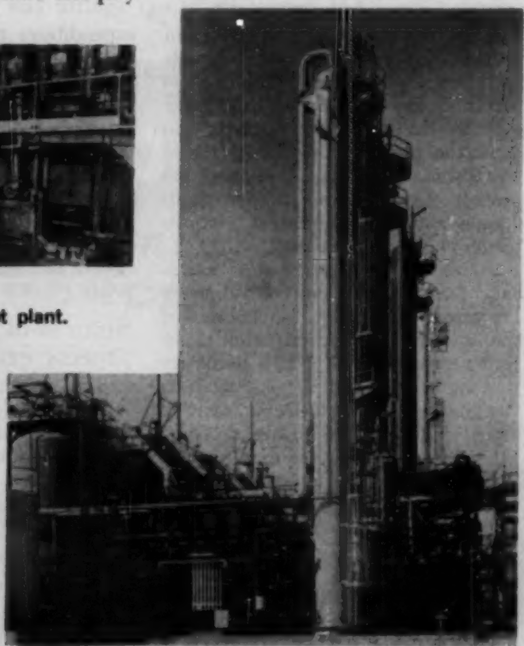


• **Data from pilot plant.**

Sources of Data

Here are three basic sources of the data for successful process evaluation.

• **from laboratory**



• **for commercialization of the chemical process**

• **from market research.**

Operating cost estimates. The operating cost estimate, sometimes known as the manufacturing cost estimate, can be derived from the operating requirements and the unit cost of each component of these requirements. Once a hypothetical plant is designed, it is possible to estimate the operating requirements. Once the plant location has been determined, the unit cost of each requirement can be established.

Operating cost estimates of this sort may be prepared either on an annual or a unit-of-product basis. If the annual basis is used, the plant onstream time must be taken into account. But in a unit-of-product basis, this factor need not be considered. Some preference has been shown by industry for unit-of-product type estimates.

For accounting purposes, it is customary to assemble cost components into separate groups. The most commonly used are: direct operating costs, indirect costs, fixed costs, and miscellaneous costs. The exact composition of these groups is somewhat arbitrary and varies from company to company. The following factors are usually considered in the preparation of operating cost estimates: raw materials, labor, utilities, services, plant general expenses, royalties, depreciation, and company overhead.

Presentation of the process evaluation

The process evaluation is presented to the management in a formal report which includes:

1. A description of the chemistry involved.
2. A description of the process.
3. Process flow sheets, equipment lists, and plot plans.
4. Corrosion problems and materials of construction.
5. Status of patents, including products, and equipment.
6. Specifications for final product, raw materials, by-products, and waste streams.
7. Raw material requirements and yields.
8. Labor and utility requirements.
9. Capital requirements and estimated pay-off time.
10. Health, safety, and fire hazards.
11. Analytical problems.
12. Recommendations.

The process evalution report serves:

1. To present a description of the proposed plant, its processing steps, its operation, its product, its economics, and its projected operations and difficulties.
2. To be used as a check list for the completeness of the development work; to point out the areas of uncertainty with expected consequences, and to recommend means of resolving them.
3. To recommend future action with respect to the progress of the project.

Fundamentally, the evaluation determines whether the proposed process steps will produce specification grade material efficiently and economically using a commercial raw material. Even though the pilot plant may show that each of the processing steps is feasible, individually and collectively, the limitations imposed by small quantities of material may leave unanswered such questions as the possible effects of by-products on recycle operations (especially with regard to product purity and process economics), the possible accumulation of trace impurities, the life of catalyst and its method of regeneration, corrosion rates of various process streams, the effect of using commercial raw materials vs. the use of laboratory grade material, and the effect on reaction kinetics of changing processing steps and geometric configuration of process equipment.

The uncertainty in the processing steps would be greatly reduced if the proposed processing chain were tried out in the laboratory or in the pilot plant and produced a product of acceptable quality. However, this type of laboratory or pilot plant work usually takes considerable time, labor, and capital. The cost of investigation would have to be balanced by the magnitude of risk entailed in applying each step or piece of equipment in the process without such a trial. In areas of process uncertainty, the process equipment should be flexibly designed to operate under a range of operating conditions. This may result in larger equipment and more extensive instrumentation, and these, in turn, require higher capital investment.

The second area of uncertainty is in the design of process equipment. For some chemical engineering operations the methods of scale-up from the laboratory or pilot plant are necessarily empirical. A lack of design procedure may be further complicated by a lack of design data. Data such as basic physical and thermodynamic properties and information regarding the process kinetics of the reaction steps, range of operating variables, mechanical data of process equipment, etc. are essential in the design of process equipment. Usually when design information is not readily available, certain assumptions are made in the design data or design procedure so that the process equipment can be designed, purchased, and installed. A safety factor is usually applied in the design in such cases. Since the assumptions the process engineer makes must be on the safe side, the addition of a safety factor results in over-designed process equipment, causing a correspondingly higher capital investment for a given design production rate.

Recommendations, based on the information submitted in the process evaluation reports are made to the management on the status of individual projects. Recommendations can usually be divided into the following categories:

1. That the research and development work for the proposed process has been completed and process data are sufficient for the design of a full-scale production plant that will perform efficiently and will produce product of specification grade, and that the risks involved in the launching of the project are negligible. Recommendations for research and development work to improve process economics should be included.
2. That the research and development work is completed with the exception of minor areas of uncertainty. The design of a full-scale plant can be started without delay. However, this will involve an element of risk in producing satisfactory material at the design rate.
3. That the research and development work does not give sufficient information for the design of a full-scale plant. The magnitude of risk involved in the operation of such a plant will be great. In this case, request will be made to the research and development departments for further laboratory or pilot plant work.
4. That the process is without economic merit, and that no further investigation is warranted.

The decision to build a plant is a commercial decision to be reached by management guided by the evaluation report, market surveys and the availability of capital to finance the project. The pressures exerted by these latter two, together with the return on investment indicated in the evaluation report, will determine the extent of the risk management is willing to accept when deciding to proceed with the design of the plant. #

Scale-up aspects of the pilot plant

The decision to abandon a plant-design research project several years after its initiation confronts the research director with one of his most distasteful responsibilities. In many instances it involves a multitude of implications both scientific and humanistic, including the reversal of a considered judgement with a permanent loss of personal prestige.

A speculative approach to engineering research is suggested here to reduce the incidence of these dead-ends. It is inexact and employs certain informalities and liberties during the research program which should be admissable under the scientific method, although they now have relatively little popularity.

A professional designer of plants will not use experimental information without some personal adjustment. To make a tenfold or twenty-fold scale-up he will not employ similarity ratios of 10:1 or 20:1. Most likely, the design of the prototype plant will include from 20 to 50% excess fat. The designer's only concern is that he is providing the fat where he believes it should be. For this type of design he requires only an indication of a response direction rather than a collection of highly refined and costly data.

There is also a matter of data displacement which is incidental to the use of plant design data. Research results are usually correlated in terms of the mean with a notation relative to the mean deviation of the data. The mean is of little value in design, since the curve or equation so obtained must be juggled upward to provide a measure of assurance that all or most of the deviations are negative. It is not the desire to learn on the large scale whether or not a plant will work but rather to make certain that it will. The curve-juggling phase may prove to be the most important step in the entire scale-up sequence.

Much of the plant design engineering research appearing in the literature relies heavily upon experimental demonstration. This is a costly approach although not necessarily a safe one. The risk stems from the associated problems of scale-up.

The scale-up problems exist, for three reasons: 1. Many of the important basic equations are unsolvable by known general mathematical techniques. 2. The basic phenomena are often interconnected; that is, the basic equations are coupled. The coupling relations are not always known, may obscure each other, and, in any case, compound the mathematical difficulties. 3. The necessary physical data required for a solution are frequently unknown and there is some belief that pilot plant data, particularly in chemical kinetics, are better than bench-scale data.

It is often pointed out that one can proceed through dimensional analysis when only a partial picture of the system has been obtained. This is not a virtue. Partial identification produces only a partial result, and can be worse than no result.

An approach which may reduce or totally eliminate research cost concentrates on the prior statement of a mechanism for determining the essentiality and design of experiments, and then requires the design of small equipment only to test the mechanism, preferably on a differential, not integral, basis.

D. Q. Kern, of D. Q. Kern Assoc., calls for better use of available mathematics before spending money for scale-up equipment.

The use of differential equations naturally confronts one with the evaluation of derivatives. Common procedures all too often lead to the measurement of variables which are usually integrals; such as, a distance, a weight change, or a time interval, rather than the direct measurement of a derivative such as the velocity.

The measured integrals may contribute different relative precisions and include sequential observations even when measured automatically; that is, it may be necessary to measure the flow and temperature changes in a stream at three or more places. The observations may be simultaneous at the various places, but the stream may undergo fluctuation throughout the distance over which the points are deployed. This is particularly true of unsteady state measurements.

Suppose it is desired to measure the average fluid velocity in a conduit. This can be accomplished by allowing fluid to flow into a can over a measured time interval and measuring the weight or volume of effluent. These are all integrals. However, it may be possible to measure the velocity instantaneously by using some invariant physical law.

Poiseuille has shown that a proportionality exists between the velocity of the fluid and fluid friction. Suspend an object in the flowing stream and measure the resistance the object affords the flow of fluid. The frictional force can be transferred to linear measurement by displacement of a spring suspending the object as shown on a graph.

Instrument manufacturers frequently use this procedure—but what does it mean? By reading the displacement of the spring one is continuously identifying the term $\partial x/\partial \theta$ when all other influencing variables are held constant. Even if the device were orginally calibrated through the measurement of integral properties it is still a device to directly measure a first-order derivative.

Assume next that rate of flow of the fluid varies such that it continuously increases, decreases, or alternately does both. By observing the displacement of the spring on a constantly moving graph it is possible to measure the second-order derivative $\partial^2 x/\partial \theta^2$ continuously and instantaneously without integrals.

Many chemical engineering phenomena may be described by first- and second-order differential equations. When the final relationship governing a phenomenon is concluded by the integration of measured derivatives, it should be noted that *integration is an averaging procedure and the precision of the final statement is fundamentally increased.* Conversely, when derivatives are pieced together analytically from the measured responses of integrals the precision of the statement is reduced due to such factors as sequential measurement and errors inherent in the integrals, but not necessarily in the derivative.

Chemical reactions furnish an excellent area in which it would be highly desirable to measure a rate directly. The differential equation approach should form the basis for scale-up extrapolation before any equipment is designed or assembled for the pilot plant. #

. . . *for product quality*

Pilot Plant

PAUL M. LINDSTEDT,
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Although the manufacturing plants for synthetic elastomers have now become well established on the emulsion polymerization process, intensive pilot plant development is still required to improve product quality, and to evaluate new sources of materials, particularly emulsifiers, extending oils, and antioxidants.

The pilot plant operations discussed here are best suited for SBR and nitrile synthetic elastomers. "Pilot plant" is used in a rather broad sense, in as much as polymerization reactions that are first tried in 5- and 20-gal. vessels are scaled up to 500- and even 1200-gal. size before trying a formula in production equipment. In this way, the pilot plant program involves a scale-up through at least two reactors which differ in volume by a factor as great at 45. Since this pilot plant scale-up is larger than the next step to the largest production reactors (3X to 10X), most of the problems of duplicating polymerization conditions are recognized in the development stage. By using the largest scale equipment, this elastomer pilot plant can produce one ton per day whenever such quantities are required. In the terminology of the chemical industry, this concept of a pilot plant also includes a semiworks facility for intermediate production.

One of the factors in determining the size of equipment for elastomer development is the "minimum sample

Figures 1 & 2. In Figure 1, below, is the pilot plant before expansion. In Figure 2, right, is the expanded pilot plant.

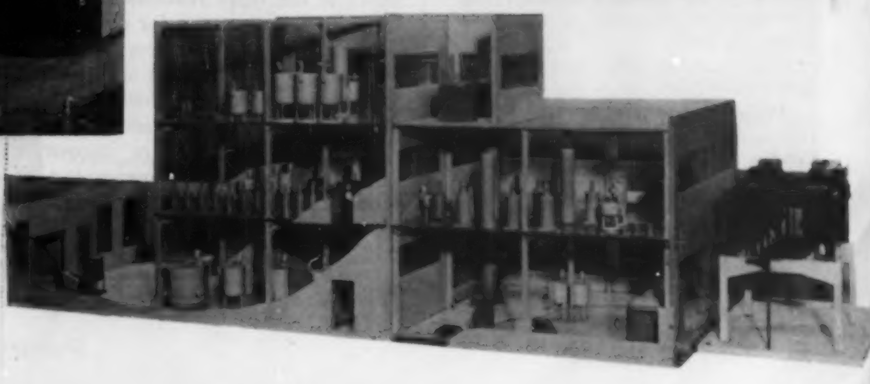

Figure 4. Scale model of the equipment layout.

Pilot Plant

continued

size needed" for a complete evaluation. Since the routine rubber laboratory physical tests, such as stress-strain, oven aging, and flex life require about ten pounds of rubber, the 20-gal. reactor has been the most useful for developing polymerization formulas. Fortunately, this size has also been suitable for developing elastomeric latices for foam rubber applications. The amount of finished, concentrated latex obtained is nearly five gallons, which is enough for laboratory evaluation in foam. Final evaluation of an elastomer development requires 800 to 1000 lb. of product for making plant-scale processing tests, such as extrusion rate, smoothness of surface, die swell, and ease of pigment dispersion. Consequently, we use 500- and 1200-gal. reactors for making ½- to 1-ton batches of rubber, which provide the tire engineers with enough rubber for two to five factory-size Banbury mixes needed for additional experimental tire tests.

It is the purpose of this article to describe some recently installed Goodyear facilities used for conducting process and product development programs on elastomers. The pilot plant discussed is organized as a separate department. Staff engineers are responsible for the technical programs, for the reporting of results, and for the proposed method of scale-up to production.

Expansion plan for building

Figure 1 shows the pilot plant as it appeared when purchased from the government in 1955. The nonhazardous building at the left housed offices, laboratories, washrooms, and a tray dryer. The three-story building housed pilot plant operations in 4800 sq. ft. of floor space. A 16-by-40 ft. shed had been previously added to the rear of the building to contain refrigeration compressors and brine circulation equipment necessary for the development of "cold" processes for rubbers. All the main electrical starters and breakers were installed within the operating building in explosion-proof cases.

The expanded pilot plant is shown in Figure 2. Laboratory and operating buildings were joined by enclosing a breezeway and two stories were added to the rear of the former operating building. To minimize hazard, all electrical starters and breakers were located in a cubicle room accessible only from an outside door and located

THE PRODUCTION OF PLIOFLEX STYRENE RUBBER

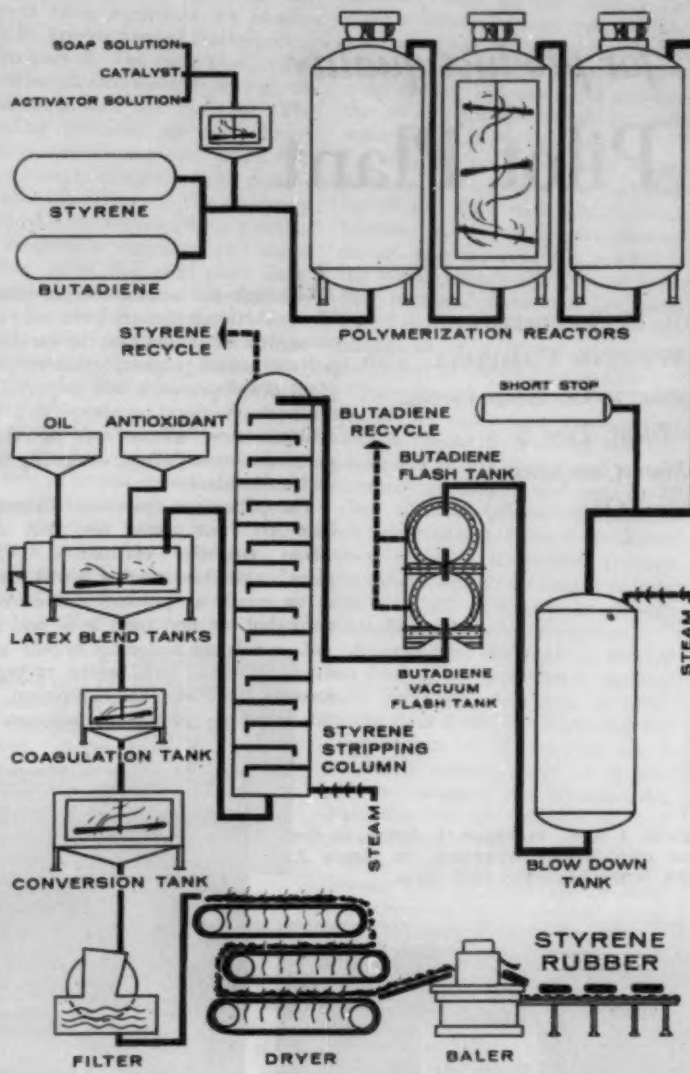

Figure 3.

Emulsion polymerization is the process most commonly used in synthetic rubber production. The raw materials, composed of the two monomers butadiene and styrene, water, soap, and catalyst, are proportioned into the continuous polymerization process. Instead of the three reactors shown in Figure 3, 10 to 14 vessels are actually used in series for controlling the 8 to 11-hr. polymerization. The removal of the excess monomers takes place under vacuum in the butadiene flash tank and in the steam distillation column. The butadiene and styrene are condensed for reuse. The polymerization is controlled to approximately 60% conversion on the monomers charged. The plasticity or viscosity of the rubber is controlled by the amount of organic mercaptan charged with the raw materials. The monomer-free latex is collected and continuously coagulated, dewatered, and dried in the type of equipment shown.

above the new floor addition. Completion of the new third floor area will be a future expansion. Floor space was increased by approximately 78% and another 22% will be available for the future.

The emulsion polymerization process was developed in 1940 and 1941. At the present time pilot tank work comprises making refinements in product quality, improvements in process control, and evaluation of new raw materials, as well as processing methods which will lower production cost. Therefore, we have equipped the pilot plant to evaluate continuous polymerization, as well as batchwise procedures for predicting plant-scale performance as accurately as possible.

Improved planning by using scale model

Prior to completion of layout drawings, a ⅜-in./ft. scale model of the proposed pilot plant buildings was built, including the major pieces of process equipment. The model, Figure 4, was then used to determine the preferred layout for new and relocated equipment. Piping and electrical drawings were prepared by the combined use of carefully prepared flow sheets and the completed model. In this way, almost all sketching by the design engineer was eliminated. Communications between the engineer and draftsmen were improved, and the time and money spent for the usual drawing revisions were reduced.

The completed model also served as a training aid for operating personnel after being used as a guide for the contractors in making their bids. Reduced time required from conception to completion of the plans permitted early reappraisal of the original cost estimates which led to several significant revisions before construction began. Finally, the model will serve as a planning guide for future equipment expansions.

Figure 5. The polished interior of one of the 27-gallon reactors.

Design features

In general, the entire pilot plant has been expanded with a view toward: securing all the engineering information needed for the process modification of a plant; permanent flexible facilities for continuing the development of elastomers on a 24-hr./day basis; versatility in handling many projects simultaneously; customer sampling of new products; and interim production during transfer of new products to a production plant. Reactions are possible at up to 300 lb./sq. in. ga. pressure and from 0 to 200°F by use of water or refrigerated brine as coolants. Either batch or continuous operations may be performed.

Table 1. Geometrical reactor comparison.

Nominal Size, Gallons	Diameter: Height Ratio
27	0.46
1200	0.54
1600	0.69
2750	0.45
2750	0.50
3750	0.71
5000	0.56

The chief problem encountered in the scale-up of emulsion polymerization involves selection of the proper agitation conditions.

Table 1 lists the vessels normally used in transferring the product from the pilot plant to production, showing the corresponding diameter-to-height ratio for each. Successful scale-up of agitation from one vessel to another depends upon maintaining geometric similitude. The selection of the shape of the 27-gal. pilot plant reactor was based on this principle, since these production vessels were already on hand and in use. By simply reducing the batch level of the 27-gal. vessel, the effective batch height is reduced, thereby increasing the D/H ratio, to match the particular production reaction desired. Two 1200-gal. reactors are also located in the pilot plant.

Table 2. Scale-up of continuous polymerization.

	Pilot Plant (11 5-Gal. Units)	Production (14 3750-Gal. Units)
Reaction (hrs.)	8.0	8.0
Modifier (pts./100)	.07-0.08	0.05-.06
Conversion (%)	60.0	59.3
Plasticity (M/L)	60	52
Total Volume (gal.)	55	52,500
Dia./Ht. Ratio	0.63	0.71
Scale-up		955

The largest scale-up of batch processes is carried out in the pilot plant by utilizing pilot plant reactors ranging from 27 to 1200 gal. in size (a 45-fold increase). This large factor will usually serve to uncover any important scale-up factor before a trial is made in production (an increase of 3X to 10X).

Conversely, continuous polymerization processes are developed in the 12-in-line, 5 gal. reactor unit and transferred directly to production in a single step. This represents a 955-fold scale-up. A comparison of typical data from this scale-up is given in Table 2. Batchwise latex reactions, especially high solids formulas, can seldom be scaled up by a factor of this magnitude. However, the continuous process lends itself to fine adjustments so readily, after equilibrium has been established, that one of the three steps needed for a batchwise scale-up can be successfully eliminated.

Of special interest are the 27-gal. stainless steel reactors, Figure 5. Inside surfaces of these reactors are polished stainless steel to increase heat transfer and reduce contamination, corrosion, and adhesion. They are suitable for 300 lb./sq. in. ga. operation to provide for future developments

Selection of the optimum agitation is a continual development problem for all elastomer recipes. There are many published examples of the effect of agitation on the physical relationships of fluids and methods for scaling up pilot plant results. Every possible use is made of these techniques,

continued

Figure 6. Detailed view of the bench-scale polymerizer.

. . . The pilot plant is organized as a production line group within development staff organization. It serves the dual function of supplying sample quantities while evaluating equipment and processes.

however, our inability to find a suitable parameter, such as heat transfer coefficient, which measures the process result for correlation with agitation conditions, has prevented direct application of most of these best known methods. Even when certain process variables can be related to product quality, for example, the effect of particle size on latex viscosity, the scale-up to retain more than one desirable feature of a colloidal product still depends upon empirical experimentation.

Another special feature is the continuously variable speed, hydraulic agitator drives on all 5-, 20-, and 27-gal. reactors. They have the advantage of reduced down time, lower labor costs for agitator speed changes, and permit investigating the effect of agitator speed changes during polymerization. The centrally located oil pumping units reduce crowding of fixtures around the reactor head, permitting batch observation through the sight ports installed on the new 27-gal. vessels.

Two tray dryers were relocated in the new building to permit doubling the laboratory space in the laboratory building and constructing offices for the chemical engineering staff and pilot plant supervisory personnel.

A multiple reactor, sized for preliminary evaluation of proposed process changes or screening of raw materials, is shown in Figure 6. Six 1⅛-gal. glass-lined reactors constructed of spool pieces of 6-in. pipe, are driven by a common agitator drive and cooled by a circulating water bath. With this unit we have been able to run as many as six batches of a factorial experiment, with the desired changes in a significant variable, and reaction results overnight. Compared to bottle polymerizers, temperature control is much better and the amount of latex produced is suitable for more final evaluation tests.

Much improvement in the reaction rates of elastomers has been realized during the 17 years that synthetic rubber has been in commercial operation. The best improvement in quality and in reaction rate became possible through the use of activated cold rubber formulations. These exothermic reactions were accelerated so that the heat transfer of the jacket alone was inadequate for temperature control; consequently, submerged cooling coil designs were developed in cooperation with refrigeration manufacturers.

These heat transfer surfaces were composed of tube bundles in which the refrigerant, usually ammonia, evaporates directly in the tubes. However, the geometric arrangement of the tube bundles presented serious cleaning problems, offsetting the shorter reaction time made possible by the submerged coils. Our largest 1200-gal. pilot plant reactor has been equipped with the Glascote Thermo-Panel cooling coil shown in Figure 7.

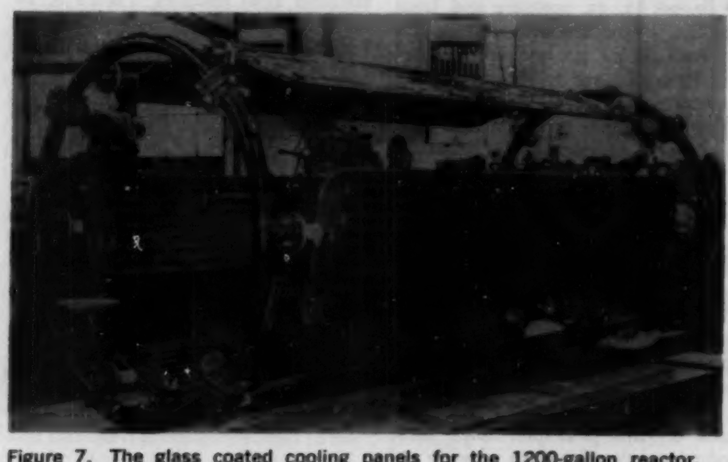

Figure 7. The glass coated cooling panels for the 1200-gallon reactor. By slightly feathering the panels to produce the desired baffle effect, a nearly three-fold improvement in heat transfer was obtained.

Figure 8. The 1000-gallon latex tank which is lifted and transported by specially-designed truck.

By slightly feathering the panels to produce the desired baffle effect, a nearly three-fold improvement in heat transfer was obtained with an increase in the total cooling surface of only 85%. In addition, the panels have required less cleaning than anticipated because of the fluid turbulence over the surface and the absence of narrow spaces to become clogged with coagulum that commonly occurs in pipe coil installations. (No other polymerizer installation of enameled panels is known.)

The latex tank shown in Figure 8 is 1000-gal. capacity and may be lifted and transported by the specially designed Dempster Dumpster truck, which is also used at Goodyear's Akron plants for hauling waste disposal bins. Two tanks of this design are used for transporting pilot plant batches whenever special processing facilities are required for completing an experimental project.

In addition to the conventional air drying equipment for finishing elastomers, a devolatilizing extruder was installed for drying and pelletizing rubber. This unit has been successfully used to develop a comparatively new method of dewatering and drying polymers.

The 2-in. double-worm devolatilizing Welding Engineers Inc. extruder, Figure 9, has a variable-speed drive (100 to 300 rpm.) and three separable, jacketed barrel sections. The coagulated rubber is separated from the coagulant on a vibrating screen. The wet crumb enters the extruder near the drive end, where the rubber is more thoroughly dewatered by the

compression of the twin screws than has been possible by conventional continuous filtration and dewatering methods. Thus, up to 85-90% of the water content of the rubber crumb has been removed as a free liquid. This removal of mother liquor from the rubber offers a considerable quality advantage because polymer so produced has much lower water absorption values. The dewatered polymer enters the vacuum section on the machine at 10 to 12% moisture, thus reducing the amount to be volatilized by the vacuum treatment. Heat is applied along the barrel by circulating hot oil in the jacket. The finished product must be cooled by a suitable take-away conveyor before baling and packaging.

Pilot plant organization

The pilot plant is organized as a production line group within the framework of the development staff organization. It serves a dual function of supplying sample quantities of experimental elastomers while evaluating equipment and processes. This group consists of a foreman, three shift supervisors, a clerk, three laboratory technicians, twenty operators, nine maintenance and three utility men.

A department foreman is responsible for the operation of the pilot plant. He reports directly to the manager of pilot plants and works closely with section heads responsible for various areas of development. Reporting to the foreman are three shift supervisors who directly supervise the technicians, the operators, the utility men, and indirectly supervise the maintenance men by issuing work requests through a maintenance shift supervisor who is a member of the maintenance group serving the same general area. All members of supervision are graduate chemical engineers, thus authority is available at all times for making decisions involving chemical engineering judgment.

A technician is assigned to each of the three shifts to do process and quality control testing of the raw materials and experimental elastomers. Special testing is often done by this group at the request of staff engineers.

A department clerk maintains an inventory of raw materials, keeps shipping and receiving records and types all technical and operating reports.

The job classification "Chemical Engineering Pilot Plant Operator" provides up to nine months as a training period. An operator who has all the qualifications and training is capable of performing all needed operations in the pilot plant according to a written specification. This includes sampling analyses for the percent solids content and the pH of latex, recording all the requested data and making the adjustments necessary to keep the process in control. Less pleasant chores, such as opening the equipment for cleaning when changing over to a different product, consume a large amount of the operator's time. When an operator has satisfactorily completed these training requirements, he is advanced to the top hourly rate permitted for this classification.

The maintenance group repairs and maintains the equipment and buildings. It also makes changes in piping and equipment as may be required by a particular experiment.

Janitor work, such as cleaning of plant and equipment, as well as loading and unloading of trucks, is handled by the utility group.

Table 3.

	Units	Percentage of Total
Supervision (Foreman and Supervisors)	5	12
Technicians and Clerk	4	10
Operators, Utility, Maintenance	32	78

Figure 9. In this devolatilizing extrusion dryer for elastometers, the coagulated rubber is separated from the coagulant on a vibrating screen.

Table 3 shows the distribution between the operating and staff personnel. The ratio of nontechnical to technical personnel in the operating group is 2.4 to 1. Technical personnel are defined as those having a bachelor of science degree.

Operating procedure

Pilot plant operations are on a six-day week, working around-the-clock. Four shifts per day in the Akron rubber industries have resulted in six days per week becoming more common than in other locations. Operators, maintenance men, and utility men are members of the United Rubber Workers, C. I. O.—collective bargaining group. All other men are salaried.

A written work request is the basis for authorizing each pilot plant operation. Where a request is received, a staff man is assigned to follow and initiate the work by issuing specifications, batch instruction sheets, etc. He is also responsible for reporting results.

Chemicals on hand at any one time vary between 100 to 200 compounds and from one pound to 10,000 gal. in quantity. An accurate account is maintained of these materials by a monthly physical inventory.

Summary

Engineering publications of scale-up techniques in petrochemical and other

continued

chemical processes from bench-scale to production size reveal an extensive use of well-known existing physical and chemical relationships for analysis of quality and process control. However, emulsion polymerization systems are dependent upon control of the surface properties of a colloid, which in turn affects processing and product quality. On-stream measurements of elastomers in latex form that correlate with final product quality need to be developed. The evaluation period for elastomer development is long and rigorous. One of the most important objectives in the pilot plant work is the demonstration of reproducibility with the least deviation in quality of the final product. Therefore, the pilot plant is regarded as a necessary intermediate step between research and production to minimize the commercial risks in marketing a new elastomer. Until the process kinetics of each of these products can be mathematically represented, we will continue to depend upon a completely equipped pilot plant rather than analogue computers for elastomer process development.

We have discussed some equipment features that exemplify the contribution of chemical engineering techniques in solving the difficult problems encountered in pilot plant work on elastomers. Even so, the complexity of the scale-up problems associated with colloidal products is still a real challenge to the ingenuity of chemical engineers engaged in elastomer development. The large number of synthetic elastomers which have reached the market places and even attained strategic importance during the last twenty years is due to the ability of chemical engineers in directing the skills of a technical team, resulting in this profitable new enterprise. #

Bench scale pilot plant

With increasing competition in the chemical industry, and much greater emphasis on research, it is inevitable that individual companies will have a lower percentage of successful projects. Here is a way to cut project costs.

Donald E. Garrett
American Potash & Chemical Corporation Trona, California

One of the most costly facets of industrial research is pilot plant operation. Equipment is generally expensive, considerable manpower is required (much of it professional), and maintenance and alteration expenses are high. Also, construction time is generally long, and the operating period may run into many months.

Efficiency of operation is increasingly important. A reduction in the cost of pilot planting could be an important step in this direction. The greater use of bench-scale pilot plants, both for intermediate and final design studies, can help achieve economies in research and development studies.

Sometimes the pilot plant step may be eliminated completely. When the process is well known, and the company has experience or a sound literature background in the operations involved, the cost of overdesign or of later modification based upon operating experience may be less than that of a large pilot plant study. Surprisingly often, a whole process (or its major parts) may be most economically handled in this manner if the engineering staff is well qualified. This is especially true if it is contemplated that the overdesign, which usually means overcapacity, may be useful at a later date. However, to eliminate the pilot plant step does involve a gamble, both of spending considerably more money than is necessary and possibly of designing a completely unworkable process—for there are many cases where processes that were successful in the laboratory were found to be unworkable (or uneconomical) on a larger scale.

As an alternative method of going directly from laboratory data to plant design, the bench-scale pilot plant has considerable merit. Such pilot

plants are built as small as practical and usually are of a size that can be mounted on a laboratory bench. This is not a new concept, for much has been written in the past about bench-scale pilot plants *1, 2, 3, 4, 5*. Their use is not as fully understood, however, nor as prevalent as economic considerations justify. Some laboratories use the bench-scale pilot plant regularly as an intermediate study between the laboratory and large pilot plant programs; others use it occasionally when the process is complex and the laboratory equipment is not suitable to establish the engineering design of the pilot plant. Both applications are useful, but they place unnecessary limitations on the data that may be obtained. With the proper engineering attention, there is no reason why bench-scale units should not often be capable of completing the equipment as well as the process design. In many cases, for the greatest economy, the final development study should be on the bench scale.

Advantages

The chief virtue of these small pilot plants is their economy of expense and time. Their scale makes possible the use of much laboratory equipment in their assembly, and any special equipment required is small enough to be readily constructed. Also, the operational control of the units, because of their size and simplicity, is comparatively easy. Each of these factors contributes toward speed of assembly and low construction and operating costs.

The small size of bench-scale units dictates that they be designed so that they are easy to operate. Otherwise the complexities of a coordinated control make the operation uneven and thus obscure the data. For this reason, a complex process must generally be subdivided into simpler steps, or the process flowsheet simplified. In most cases this is not a serious limitation, for intermediate surge-flows may be held, and it is always desirable to concentrate the study on the most difficult steps. The net result is that bench-scale units are often much simpler to operate, although programming and data analysis may be more complex.

Bench-scale units are versatile. The fact that modifications can be made easily means that they are ideally suited for the screening of a wide variety of variables and designs. In this manner, the specific equipment design features and the conditions of optimum operation can generally be found rapidly and reliably. This feature is so important that, even for the cases where larger tests are justified to more precisely define the optimum conditions and design, extensive preliminary screening can often be most effectively done on a bench scale.

As a final and obvious advantage, the units require less floor space and head room, and the chemicals, solution, utilities, etc. needed in their operation are correspondingly small.

Disadvantages

Of course, bench-scale pilot plants are not without their disadvantages. The greater scale-up factor between the pilot and plant units is the most obvious. Also, some operating techniques and problems may not be discovered in small-scale studies. The wall effects and different geometry of the small units may be such as to make impossible the precise design (scale-up) of the plant equipment. Finally, handling difficulties, such as

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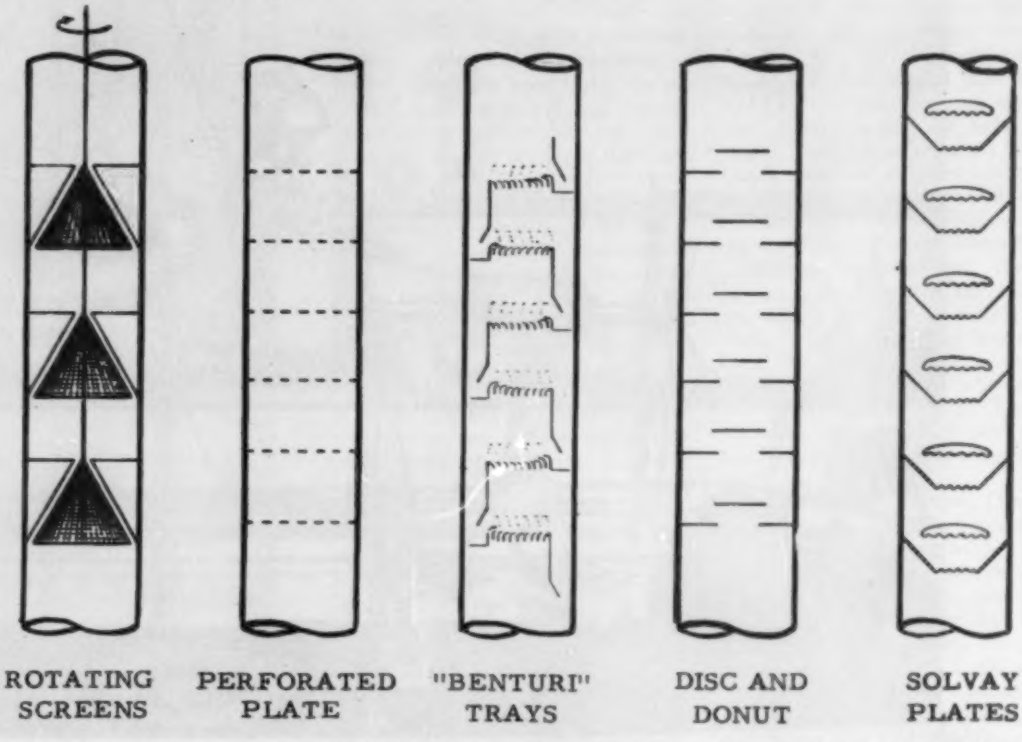


Figure 2. Schematic drawings of typical bench-scale absorption column designs used in this study. (4-in. diam., 6-ft. height.)

... The greatest challenge of bench-scale pilot plant work is the demand that it places on the engineering principles involved.

plugging, heat transfer problems, and flow control on some processes, may make the use of small equipment an impossibility. For such reasons, or because of the need to produce market development quantities of the product, large pilot plants may be imperative. Even in these cases, however, the use of bench-scale units, either before or concurrent with the larger study, will generally allow a speeding up of the project and a total economy in the development program.

Design demands

The greatest challenge of bench-scale pilot plant work is the demand that it places upon the engineering principles involved, and this is probably the major factor in its limited use at the present time. To obtain the maximum amount of data on this small scale requires that the design principles be accurately considered. It is much more important to design a unit to simulate the critical control conditions, considering the mechanisms involved, than to have geometric similarity to the full-scale equipment. It is also necessary to be aware at the beginning of the experiments of the final scale-up correlations and methods that will be used so that the correct data may be obtained. The individual vessels, even though small and simple, must be carefully designed and constructed. Also, the auxiliary equipment (pumps, etc.) must, whenever possible, meet scale-up as well as process requirements. The success and extent of the data obtainable from bench-scale units are largely dependent upon this exact design of the vessels and equipment. Standard laboratory equipment to be used must be carefully selected to meet all the requirements of the process.

The design methods for bench-scale pilot plants involve most of the general pilot plant technology, *6, 7* as well as various specific techniques. In order to illustrate the latter, a few examples of actual projects are discussed in some detail.

Crystallization pilot plant. Figure 1 shows a bench-scale pilot plant for the production of a heavy inorganic chemical by a low-temperature crystallization process. The flowsheet, as outlined by laboratory investigations and preliminary engineering studies, involved several difficult processing steps, but much of the operation was similar to existing processing methods. Since time (and, as always, expense) was important, it was decided that only the minimum pilot planting would be done. This meant that bench-scale studies would be made of the difficult portions of the process and large pilot plant equipment would be operated only if necessary on the basis of the bench-scale work.

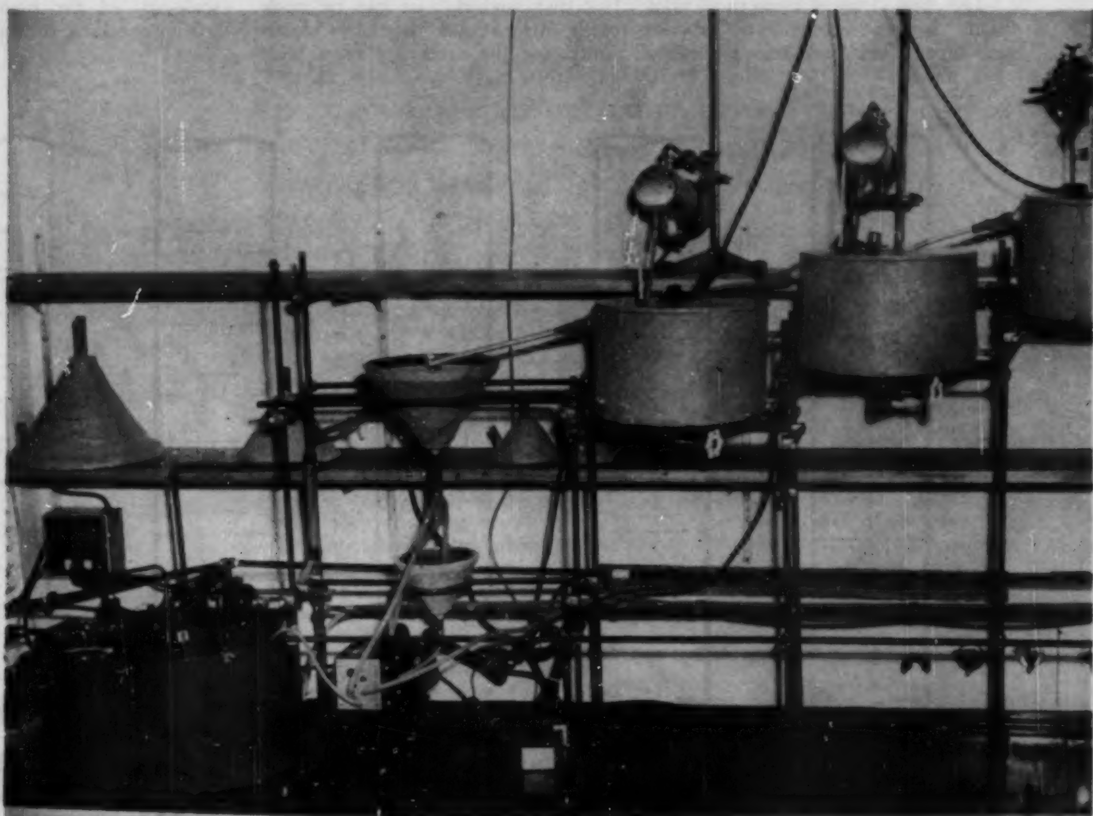
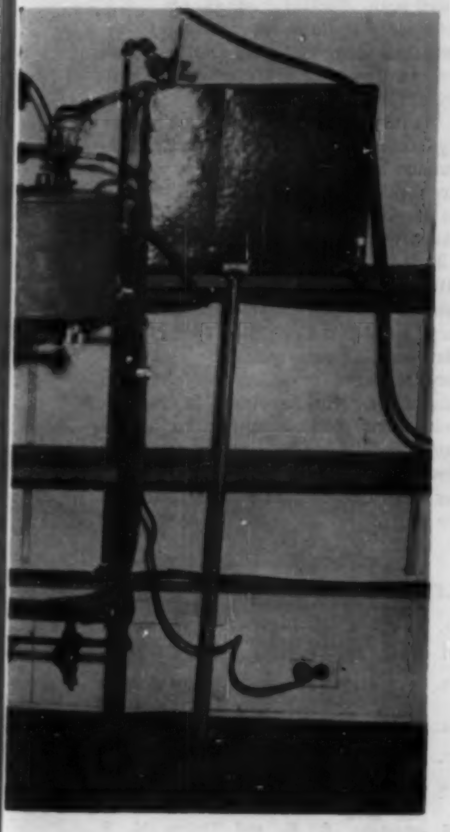


Figure 1. Multiple agitated tank crystallizer used as first bench-scale equipment to test process methods in the study.

The brine used as the raw material contained many components, and a second solid, in addition to the desired one, crystallized out at the most economical terminal temperature. Its rate, however, was slow, possibly allowing it to remain supersaturated if rapidly cooled. Alternatively, if desired, both salts could be crystallized and then physically separated or recrystallized. With both cases an additional salable product could be produced: in the first method, through later processing of the brine, and perhaps directly in the second method.

The first bench-scale equipment to test the process and compare these alternative methods employed the multiple-agitated tank crystallizer shown in Figure 1. Classification cones, feed and product tanks, pumps, and cooling equipment completed the crystallization section of the process. Level control was accomplished by means of overflow pipes, and temperatures were controlled by (off-on) thermoswitches operating small centrifugal pumps circulating a low temperature cooling brine. Process flows were regulated by variable speed Sigma (finger) pumps. Screen and chemical analyses were made of the product at regular intervals. This equipment allowed a rapid and thorough examination of the variables: retention time, temperature, crystallization rate, ΔT_{LM} (liquor to coolant), sludge density, recycle method, and solids separation. By suitable equipment and operating changes, the pilot plant could be converted to a rapid cooling arrangement, and many of the same variables studied. The clear overflow from the settling cones could be held and further tests conducted (using seeding techniques) to recover the second supersaturated product. This equipment was relatively simple, but was still closely designed for both capacity and function. Size was fixed by the pump capacity and convenience in vessel size.



The crystallizers are a more difficult operation to simulate for vacuum or forced circulation units. Agitated tank crystallizers are easy to run and may be directly scaled up, but vacuum units are generally too difficult to control precisely on the bench scale. However, by designing to regulate the controlling crystallizing conditions —maximum supersaturation with the vessel (or piping), crystallization rate, sludge density, fine particle control, etc.—any type of crystallizer may be simulated with simple equipment. In this case, a small external cooler was built on an open tank crystallizer, allowing most of the variables of forced circulation units to be studied.

The pilot plant was run by one operator on a three-shift basis (because of the long residence times and the resultant slow approach to steady state on some of the runs), five days a week for one month. A number of different equipment modifications were made and all of the major variables studied. As a result of this study the decision between the two major processes, and design of most of the equipment, could be made directly. However, the exacting demands of separating the two solids required that a limited medium-sized pilot plant check be made on a specific crystallizer, as well as on the fouling limits of one heat exchanger.

Not all processes associated with the crystallization unit operation can be easily duplicated on a bench scale. However, if the required degree of exactness of the final process design is within the limits of scale-up accuracy (often the case), the final design can be taken from the bench-scale data alone. Operational control of medium-sized crystallization pilot plants is often difficult so that, compared with bench scale, little is gained in larger units until a very large and expensive size is reached. This provides more incentive to work with smaller units.

Absorption pilot plants. The use of small towers to pilot plant absorption studies is a widespread practice. Much mass transfer data for such small-scale tests is available in the literature, and the correlation methods for analyzing and extrapolating data are well developed. Unfortunately, however, accurate scale-up from bench-sized to large towers requires either direct experience or some large-scale tests. Even so, the use of bench-scale towers can be a very economical step in an absorption process study.

An example of this type of study is the test made to increase the capacity and to improve the efficiency of an existing set of absorption towers carbonating a brine to form sodium bicarbonate. This study was conducted in a short (6-ft.), 4-in. diam. column, mounted on a laboratory rack. On this scale the variables could be fairly quickly examined, and various column designs roughly tested. Plugging and absorption characteristics were determined for the five columns shown in Figure 2. Because of the uncertainty of scale-up to large towers, a 16-inch diameter column was briefly operated to check the two most promising designs at flow rates close to their optimum operating conditions. This combination of detailed bench-scale and brief pilot plant studies gave the desired data at the minimum operating and capital costs. By using mass transfer correlations obtained from the bench scale and adapted to the plant towers, an exact guide was established for obtaining optimum efficiency under any specific production demands.

Heat exchange study. Heat exchange is another one of the unit operations that can often be readily tested on a bench scale. Since larger scale tests can also be done comparatively easily, the bench-scale studies are not too frequently employed. Even so, the same advantages of quicker and less costly studies with bench-scale units are applicable.

Complex process studies. Complete, complex process studies (especially if cyclic flows are involved) can be much harder to accomplish on a small scale than the simpler process or single operations studies, but at the same time, can be much more economically conducted than when using larger equipment. The greatest problem with complex-process bench-scale pilot plants is to subdivide the process

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Bench scale

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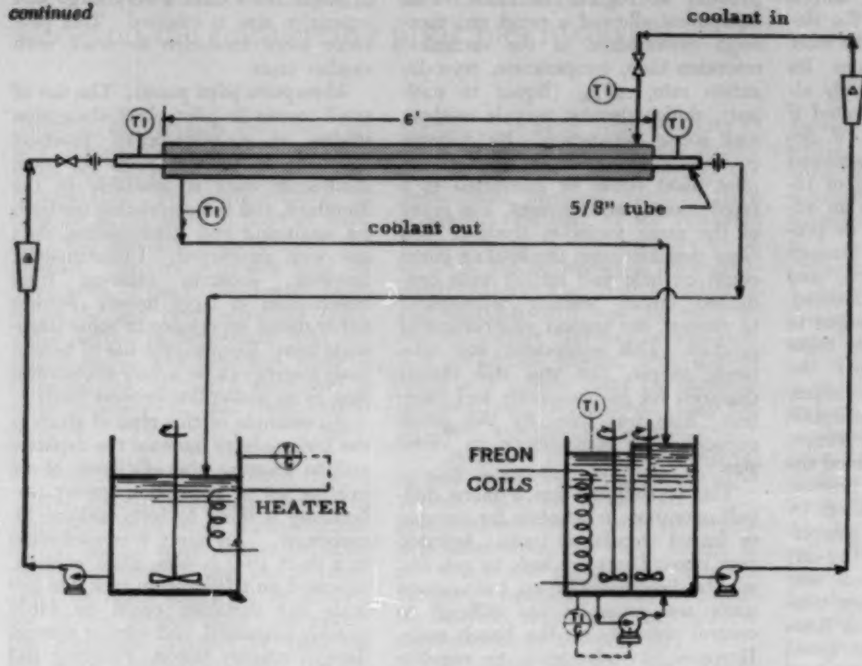

Figure 3. Schematic diagram of the bench-scale heat exchanger used in the study.

into steps that can be handled on a small (and generally less instrumented) scale. The process control must be fairly simple. This precludes installing and attempting to operate the entire process continuously. Fortunately, there are usually a sufficient number of places in an operation where liquors or materials can be stored before proceeding with a succeeding step. Such compartmentalizing complicates the analysis of the data and requires some compromising and adjusting of conditions to integrate the substudies. It may even limit the extent of the bench-scale study, but generally all or most of the pilot planting can be performed.

An example of such a study is the recovery of a heavy metal from a brine solution. The steps were: reagent conditioning and metal precipitation, reagent separation from the metal, and three separate steps of metal purification and conversion to the desired form. Each recycle stream was stored and returned to the next cycle of the earlier step. Conditions were optimized for each step independently before going on to the succeeding step. This intermittent processing was a compromise toward continuous operation but was quite efficient in time and expense and, after a few complete cycles, was reasonably representative of a continuous process. As with many such studies, at times it was necessary to return to laboratory tests because of mechanical or other problems, and much equipment revision was required. However, the study was completed in about two months' operation (one operator, two shifts per day, five days per week) and was sufficient to adequately define the economics and plant design for the process.

Summary

The foregoing are isolated instances of bench-scale pilot plant studies. They do, however, serve to illustrate some of the methods of their use and utility. Bench-scale pilot plants are not a new research and development tool. They have long been used for either an intermediate study step or for occasional studies. Their recent significance lies in the need for improved efficiency and lower costs in research and development work. Since the pilot plant phase of development work is so expensive, any savings here are worthwhile. Also, the extension of bench-scale studies to cover much, if not all, of the pilot plant investigation is more possible now than it has previously been. The unit operations design theory has become much better known, and mathematical relationships to allow extrapolation and correlation of data are more available. At the same time, considerable progress has been made in recent years in pilot plant technology, both in equipment and scale-up knowledge. Small-scale control instruments have become standard laboratory equipment, as have stirrers, pumps, and feeders designed for continuous and rugged duty.

Meanwhile, large-scale pilot planting costs have gone up, and the difference between the cost of adequate, large pilot plants and the money to be saved by a more accurate design has often become vanishingly small. All these factors direct increasing attention to the bench scale as the "standard" pilot plant step, with the large pilot plant required only in special and limited studies. This will require more emphasis on chemical engineering fundamentals in the development studies, and more ability and confidence in making the final design from lesser data. The rewards for this attention to bench scale can be great.

LITERATURE CITED

1. Donnell, C. K. *Petrol. Eng.* *23*, No. 13, C11-16 (1951).
2. Grothe, J. D. *Chem. Eng.*, *63*, 239 (June, 1956).
3. Hoog, H., Leendertse, J. J., and Reitsma, H. *Ind. Eng. Chem.*, *47*, 1104 (June 1955).
4. Kapnicky, J. A. *Ind. Eng. Chem.*, *48*, 47A (Aug. 1956).
5. Roth, E. R. *Ind Eng. Chem.*, *46*, 1428 (July 1954).
6. Jordan, D. G. *Chemical Pilot Plant Practice.* New York. Interscience Publishers, Inc., 1955.
7. Johnstone, R. E., and Thring, M. W. *Models and Scale-up Methods in Pilot Plants.* New York: McGraw-Hill Publishing Co., 1957.

the operators report on SAFETY in air and ammonia plants

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The fourth and final part of CEP's exclusive report on the informal roundtable session takes up, in detail, the direct problems involved in actual explosions experienced by the companies represented at the session.

BOLLEN, Dow (Canada): On December 13, 1957 at about 4:15 p.m. an explosion and fire occurred at the ammonia plant of the Dow Chemical of Canada Ltd., in Sarnia, Ont., which destroyed the hydrogen purification unit. Two men were fatally injured and one man was seriously burned.

The Dow Emergency Plan (a preconceived plan designed to train and coordinate plant personnel in the performance of specific duties in the event of major disasters) was put into effect immediately. The value of this plan was evident by the lack of panic and the smoothness with which the plant was shut down and isolated by operating personnel, and in the effectiveness of the fire fighting force and various supporting operations. It was possible to confine the fire to the area of the hydrogen purification unit. The fire, fought entirely by Dow personnel, was brought under control by approximately 5:00 P.M and was completely extinguished by approximately 8:00 P.M. The large inventory of liquid hydrocarbons in the various vessels and exchangers which had to burn off made it almost impossible, and in fact undesirable, to extinguish the fire any earlier.

The hydrogen purification unit, in which the explosion occurred, was located on the north side of the compressor building so that the south side of the unit formed part of the building wall near the main control area of the plant. This arrangement permitted a great part of the blast to pass directly into the building. Extensive damage was done to most of the piping and a large percentage of all the equipment in the hydrogen purification unit. General damage was done to nearby piping and control panel instrumentation of the ammonia plant, and some damage to structural steel, roof, and windows of the ammonia plant building.

The hydrogen purification unit, in operation since early 1955, was designed to process hydrogen-rich streams from two nearby oil refineries and a demethanizer overhead stream from the adjacent Dow ethylene plant. Hydrogen content of the refinery streams may vary from

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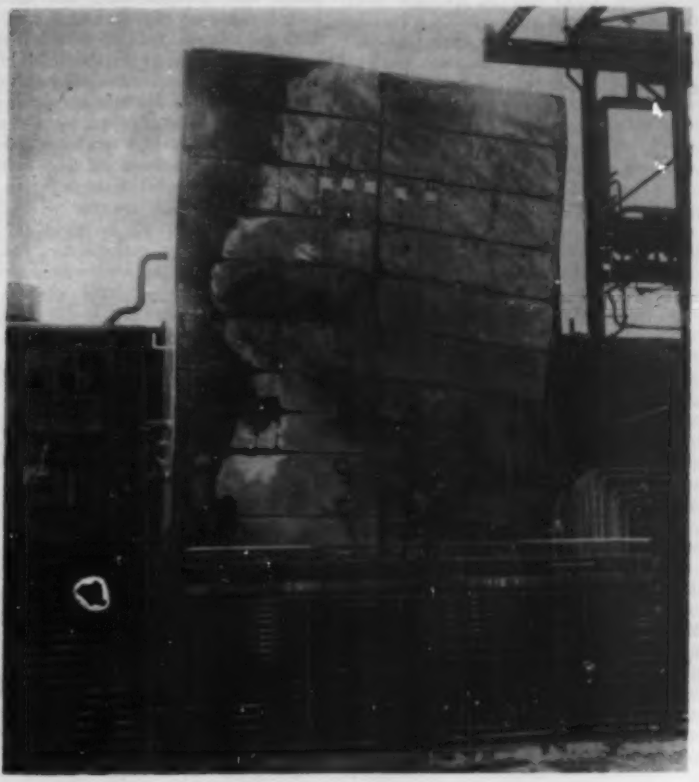

General view of the cold box from the north side after the fire had been extinguished.

Close-up of cold box from the north side, showing extent of damage to the lower section.

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70 to 93 volume percent. The remainder is essentially saturated hydrocarbons, predominately methane. The ethylene plant stream contains from 30 to 35% hydrogen and the rest is mostly methane with about 2 to 4% ethylene and ethane, 0.5% CO, and a trace of acetylene.

At the time of the explosion, the ammonia plant (air separation unit, hydrogen purification unit, and ammonia synthesis system) was operating normally at about 60% capacity. The hydrogen purification unit, the "cold box," consisted of low temperature processing equipment, fabricated of stainless steel and copper, most of which was inside the cold box casing and completely embedded in rock wool insulation packed at a density of 10 to 12 lb./cu. ft. Processing consisted of successive cooling of the raw gas by heat interchange, condensing out the hydrocarbons and their expansion to vapor to recover refrigeration, followed by a liquid nitrogen scrub in a plate column.

All of the equipment used, except the ethylene precooler, the ammonia-refrigerated ethylene condenser and the ethylene receiver and connecting piping, were inside the cold box casing. The combined hydrogen-rich gas streams, compressed to approximately 180 lb./sq. in. ga., free of CO_2, moisture, dust and other impurities entered the first heat exchanger at about +40°F. In this exchanger, the combined feed gas was cooled by countercurrent heat exchange with the product streams leaving the unit. The heavier hydrocarbons were condensed in this element and were withdrawn as liquid at about 40°F.

The gas proceeded through an ethylene cooled exchanger and on into the second heat exchanger where the ethane and the remaining propane and propylene in the feed gas were liquefied. The gas, leaving the second exchanger was further cooled in the third exchanger, where it was submitted to the reflux action of liquid ethane, which was designed to dissolve an appreciable amount of the acetylene present in the feed gas. The liquid fractions withdrawn from the lower parts of the second and third exchangers were expanded to near atmospheric pressure and were passed back through the tube bundles of the exchangers. The combined fraction from these made up the C_2-rich stream delivered as a gas at the outlet.

The remainder of the feed gas was further cooled in a fourth exchanger where the main part of its methane content was condensed, with a small amount of nitrogen and CO. Further methane removal was carried out in the reflux condenser where the feed gas was cooled by the refrigerating action of residual CO and liquid nitrogen boiling in the low pressure shell of this exchanger. Free from most of its original methane content, the gas entered the liquid nitrogen scrubbing column, a plate column in which the gas rose through the plates countercurrent to a stream of liquid nitrogen which absorbed the CO and the balance of the methane.

The gas, now free of all hydrocarbons and most of the CO, came out the top of the column where it was mixed with an additional amount of nitrogen. The composition of the gas mixture at this point was approximately the stoichiometric necessary for ammonia synthesis. This gas mixture proceeded back through the heat exchangers to the inlet of the synthesis gas compressors. The refrigeration necessary to run the hydrogen purification unit was supplied by a cascade system in which high pressure nitrogen was cooled by a closed ethylene refrigeration system, cooled in turn by an ammonia refrigeration system.

After the fire in the hydrogen purification unit had been extinguished, the unit and the surrounding area were roped off and left undisturbed until personnel investigating the accident had had an apportunity to view the wreckage. The rock wool and loose debris were then cleared away to expose the vessels and the piping.

All evidence indicated that the explosion had been inside the cold box casing, but outside the equipment. Careful examination of all the pipe and vessels revealed no evidence of rupture by internal pressure or explosion, or any evidence of mechanical failure. The center of force, although not too clearly defined, was in the general area of the liquid nitrogen scrubbing column at an elevation of approximately 13 feet. The force of the explosion tore the top head off the cold exchanger and collapsed and tore loose the bottom head of the reflux condenser. Support legs under other nearby units were shattered allowing the vessels to drop, causing separation of numerous lines.

Walton   Bollen   Funk

The liquid and gaseous hydrocarbons released from the broken lines supplied more fuel for the fire. Many lines were so badly melted where the liquid and gaseous hydrocarbons, present in the lines and vessels, had ignited at the open fractures of the lines that it was impossible to determine which of the line separations were at joints. Other lines were torn and severely crushed. All copper lines, near what was believed to be the center of the blast, showed evidence of having been subjected to severe external force. These lines were badly mangled and crushed flat. There was also evidence of external forces applied to the units whose legs had collapsed.

Experts familiar with the investigation of explosions were of the opinion that the general nature of the explosion and the limited extent of the damage suggested that the explosive force was characterized by high velocity and relatively low total energy. The nearly flat trajectory followed by pieces of valves, clods of rock wool, and other debris which were hurled completely across the compressor building and out through the windows on the opposite side of the building with sufficient force to strike and plaster against vessels outside the building, supported the suggestion of a high velocity explosion. That the severest damage was limited to approximately one quarter of the cold box and adjacent equipment, provided further evidence. The effect compared to that to be expected from two or three sticks of dynamite.

Purging nitrogen was introduced to the cold box casing through a 1-in. perforated sparger pipe which ran along the concrete pad the length of the cold box. Inspection of the nitrogen purge valve after the explosion showed the valve, a 1-in. gate valve, to be open approximately ⅜ of a turn. The valve normally operated with 200 lb./sq. in. gauge nitrogen on the upstream side.

The cold box casing was not air tight. It is quite probable that the nitrogen purge was insufficient to prevent air from entering the casing, permitting air and hydrocarbon mixtures.

In view of the concentrated nature of the damage it was agreed that it could not have been caused by a simple gas phase explosion, because this type of explosion would not have had sufficient energy to shatter equipment, provide the high velocity, nor exert the unequal blast force within the casing evidenced by the limiting of the explosion to the lower half of one end of the cold box.

A theory which fitted all the evidence proposed that a mixture of partially liquefied air with oxygen content possibly in excess of 40% to 50%, and hydrocarbons in either liquid or solid phase, accumulated in the vicinity of the bottom of the liquid nitrogen scrubbing column and the connecting line to the reflux condenser; that it was the ignition of this mixture which caused the explosion.

The waste nitrogen from the bottom of the nitrogen scrubbing column, at about 180 lbs./sq. in. ga. and −320°F. was expanded through a valve to nearly atmospheric pressure. This expansion cooled the waste nitrogen stream down to a temperature below −325°F so that this line was the coldest part of the cold box. Since the temperature for the liquefaction of air at atmospheric pressure is about −310 to −311°F, it would be possible for air to condense on the surfaces around the bottom of the column and along the line and saturate a small volume of rock wool in the vicinity of these sections of equipment with oxygen-enriched liquid air. This oxygen concentration may have been further increased, to some extent, by a refluxing process around the bottom of the nitrogen scrubbing column and the line.

Hydrocarbons leaking into the casing of the cold box from flanges and/or line joints could be expected to dissolve in the partially liquefied air and (through a similar refluxing process to that of the air) could have been concentrated to the point where they exceeded their solubility, causing solid hydrocarbons to exist in the presence of oxygen-enriched liquid air. The presence of hydrocarbons either in the liquid or solid phase in oxygen-enriched liquid air would have made a highly explosive mixture, requiring only ignition to cause an explosion such as occurred in the casing of the hydrogen purification unit.

It was recognized that a large quantity of energy would be required to detonate a liquid mixture of air and hydrocarbons. However, hydrogen was also present in the cold box and a gaseous mixture of hydrogen and air would require only a small quantity of energy for ignition. It was considered that this could have served as a fuse to carry a flame to the liquid mixture of air and hydrocarbons.

The question of ignition is still open to speculation. In all probability it will never be answered to everyone's satisfaction. Some possible sources considered by the investigating team were:

1. **Internal explosion within pipe lines or vessels, or their mechanical failure.** There was no evidence that an explosion internal to the lines or vessels had occurred, nor of any mechanical failure preceding the explosion and fire.
2. **Static sparks from particles either inside or outside the cold box.** It was theorized that static charges could have been generated by drops of liquid air dripping from the pipes and vessels.
3. **Sparks from electrical equipment.** The nearest electrical equipment was the instrument panel and those instruments containing electrical circuits were supplied with air purge, in use at the time of the explosion.
4. **Sparks from oxyacetylene cutting operation in the vicinity of the cold box.** This appeared to be the obvious source of ignition since the cutting was done on a steel structure approximately six to eight feet west of the cold box. However, the investigation revealed that the cutting had been completed before the explosion. The interval of time could not be definitely established, but it was believed to be between one-half and three or four minutes. The immediate area between the cold box and the location of the cutting operation had been carefully tested with an explosimeter and found to be free of combustible gases prior to the start of the job. Hot work permit had been issued for the cutting job which took about 20 minutes to complete.
5. **A secondary nonluminous hydrogen flame ignited by the welding might have burned unnoticed for some time** before the exact conditions occurred for propagation of the flame into the box.
6. **A steam hose was used to quench sparks from the cutting operation.** A static-free hose was used for this operation but tests subsequent to the explosion showed that the conductor embedded in the hose was open-circuited. This may have resulted from damage in the explosion and fire, since the hose was badly charred by the fire. This hose could have been the ignition source.
7. **Two men were working in the area at the time of the explosion.** A spark could have been caused by striking of metal tools or equipment.

Subsequent to the explosion, flame propagation through rock wool was investigated using flames produced by hydrogen-air, ethylene-air, and hydrogen-oxygen-nitrogen mixtures containing higher amounts of oxygen than found in air. These tests indicated that only the high-oxygen containing mixtures would propagate a flame through rock wool. While verifying the effectiveness of rock wool as a flame arrester, these tests did not eliminate the external sources of ignition from further consideration. All of the sample lines, purge lines, and deriming lines exited from the cold box at the west end. Inadequate sealing of these lines and possible voids or channelling of the rock wool along the lines inside the cold box could have permitted a flame to pass into the cold box. Thus, any source of energy either inside, or immediately outside, the cold box could have initiated the explosion.

The prime purpose of the investigation was to determine the cause of the explosion so the necessary steps could be taken to eliminate any possible future recurrence. On the basis of the investigation and the conclusions drawn by the investigating team, it was felt that this could be accomplished by eliminating the oxygen from the casing of the cold box and/or eliminating the gas leakage from vessels, flanges, and lines into the casing of the cold box.

Although it was practically impossible to eliminate all possibility of leakage of hydrogen and hydrocarbons from equipment at these operating temperatures, it was possible to redesign the equipment to reduce leakage to the absolute minimum. The elimination of the oxygen, however, was practical and feasible. The following changes were some of the major steps taken in connection with the reconstruction and operation of the new cold box.

1. The outer walls of the cold box were made as tight as possible. All panels and bolts in the casing of the box were carefully sealed in place and seals were provided around valve stems and pipe lines passing through the panels of the box. The inner surface of the panels was given a protective coating to prevent internal corrosion.
2. The nitrogen purge system was redesigned to give better distribution throughout the cold box. Instrumentation and necessary alarms were provided to assure a continuous flow of dry purge nitrogen to the cold box casing, to measure the pressure within the casing so that it could be maintained above atmospheric pressure at all times, and to sample the gas content of the cold box so that the oxygen content could be maintained below 2%.
3. Sample probes were installed at several locations in the cold box so that the gas content could be sampled and analyzed. Analyses for hydrogen, hydrocarbons, and oxygen are carried out regularly, in addition to the continuous oxygen-content indication provided by the oxygen analyzer.
4. A procedure was set up whereby the casing of the cold box is thoroughly flushed with dry nitrogen until the oxygen has been displaced each time the cold box is started up after a shutdown. This is assured by analyses of the vent gas from the various sample points.
5. To help minimize gas leakage from vessels and lines within the cold box, all vessels with flanged heads were replaced with vessels of all-welded construction, and all vessels and lines, formerly of copper, were replaced with stainless steel. The only flanged connections were

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those located at control valves. All other piping and vessel connections were made by Heliarc welding. All field welds were radiographed for flaws. Prior to start-up, the entire unit was pressure-tested then filled with Freon, and inspected for leaks with a halide detector.

6. All vessel legs which formerly were carbon steel, were replaced with stainless steel.
7. All vessels in the cold box were individually grounded to prevent build-up of static charges.
8. The previous location of the cold box had proved unsatisfactory for maintenance work due to the generally crowded nature of the plant in this area. Therefore, the cold box was rebuilt away from the building and operating area. It now is operated by remote control from the original control area.

The new hydrogen purification unit has now been in operation for approximately 3½ months and appears to be functioning well in all respects. Recent analysis of the gas content within the casing of the box showed it to be 99.7% N_2, 0.2% O_2, and 0.1% H_2. It is felt that the possibility of an explosion, like the one just described has definitely been eliminated.

This report of the explosion and subsequent investigation is given with the sincere hope that the information may help to prevent similar disasters. In closing, I would like to point out that the conclusions drawn and the theories formed are those of the Dow Chemical Company of Canada, Limited. As in most explosions, a lot of theorizing had to be done. We don't pretend to have all the answers as to how and why the explosion occurred, but we have tried to the best of our ability to match theory with fact.

CHAIRMAN WALTON: To my way of thinking, this places a premium on tight cold boxes and good purge. The tight cold box has to be made pretty much in the original construction, or else in a major revamp of the equipment. I'm impressed by the 3-4,000 cu. ft. of purge. That certainly shows you did a great job of making a tight box.

FUNK, German Linde: I would like to read a note from Dr. Karwat which gives some explanations for explosions in hydrogen purification plants. More than 30 years ago our company learned about explosions in hydrogen purification cold boxes when the first units were built to recover pure hydrogen and to yield synthesis gas of 75% hydrogen and 25% nitrogen, by applying low temperature techniques for separating the components of coke oven gas. In some cross sections of exchangers in the ethylene fraction we observed deposits of brown resins which could ignite by themselves and decompose. These resins proved to be similar to deposits in city gas lines. These are the products of the reaction of NO and NO_2 with dienes, especially cyclopentadienes. The low temperature promotes NO molecules to form double molecules $(NO)_2$, their oxidation to $2(NO_2)$, and then the agglomeration of NO-NO_2 to the double bonds of dienes $=C-C=$. The dienes eventually polymerize to nitrosate and nitrosite complexes and to resins. These compounds are relatively soluble in liquid ethylene. However, the vapor pressure is so low that they cannot be completely evaporated with ethylene

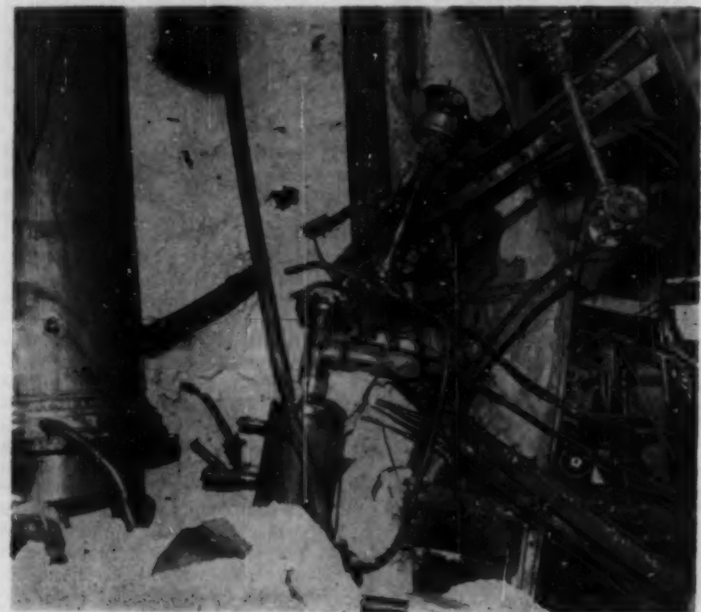
Wright Mason Jones

and they, therefore, accumulate in the heat exchangers, and very likely in blowdown lines, also. These resins decompose and explode at ambient temperatures. It, therefore, is essential to remove these deposits at low temperatures. This can be accomplished by washing the resin-covered surfaces with acetone or a solution of sodium with methanol. Only then can the heat exchangers be safely heated to ambient temperatures, and cleaned afterwards with caustic soda. Such a cleaning procedure is necessary after about one to two liters of NO have entered the cold box. Of course, we try to keep the NO content down by introducing as little smoke gas as possible into the gas chambers, when producing coke oven gas. About 80-90% of the NO can be removed by dry desulfurization. We have developed a process which lets NO react with chlorine dioxide, after which the gas is scrubbed by caustic-containing thiosulfate. Sometimes water-scrubbing under pressure is used. However, the water must test out as free from microorganisms which produce NO to avoid increasing this most undesired component. The danger of explosion related to NO must not be underestimated. For instance, the rupture of a ⅜-in. drain line caused the fire of escaping pressure-gas which destroyed the roof of the building and the downpour of debris damaged the machinery.

Another point which I would like to mention is that if hydrogen is cooled to freeze out CO and nitrogen in boiling liquid nitrogen under vacuum, it is necessary to keep the oxygen content of the nitrogen very low, below 0.5%, to prevent infiltration of hydrocarbons into the circulating nitrogen through leaks in the exchangers. Check this by analytical methods. Otherwise, oxygen in the refrigeration liquid would enrich above the tolerable limit and react with hydrocarbons to initiate an explosion.

BRUNI, Soc Edison, (Italy): In February of 1957 there was a violent explosion in the hydrocarbon purification cold box in a plant in Porto Marghera, Italy. We considered that there were two explosions. The first was in the cold box and then an awful explosion outside the box. We think if the explosion had been only in the box the effect would have been small.

DePAUW, Carbochimique: I'll try to explain this story. A high pressure part of the equipment had been inadvertently connected to a low pressure part. Apparently there had been some leak from the high pressure part towards the low pressure part, so that a build-up of pressure occurred in a small heat exchanger,



Close-up of cold box from inside the building, showing extent of damage to lower southwest corner.

normally in low pressure service. The bottom was ripped off by the pressure and as a result of that, a small explosion resulted which damaged one of the nearby high pressure lines. This caused a terrible fire and explosion which killed, I believe, one man.

Materials and their inspection

WRIGHT, Standard Oil (Ind.): The subjects to be covered are:

1. Corrosion of a Brown-Boveri nitric acid plant air compressor.
2. Pressure-gauge bourdon-tube failures and new specifications.
3. Ammonium nitrate tank leaks and corrections.
4. Brass trim in valves in ammonia service.
5. High pressure valve stem failures.

Corrosion has been encountered in the last four stages of the 14,000 cu. ft./min. Brown-Boveri nitric acid plant air compressor. The corrosion product was identified as Mohr's Salt: $FeSO_4(NH_4)_2SO_4 \cdot 6H_2O$. This corrosion was caused by condensation of moisture containing SO_2 from the saturated air in high pressure stages. The compressor has interstage cooling.

Arocoat, a coal-tar epoxy resin which has a relatively low moisture-vapor transmission and broad chemical resistance, was applied to the compressor case, diffusers, and rotating assembly after these parts were thoroughly sandblasted. The compressor has been run only a short period of time since this application, so it has not been possible to evaluate the results.

Vapor-phase inhibitors are being studied and may be used if the Arocoat is not satisfactory. Alloy diffuser sections have been ordered and will be installed at some later date. It may also be necessary to obtain alloy wheels for the last four stages of compression.

MEA and caustic systems were inspected after almost two years of service and appeared to be in excellent condition. Kontol 121 is used as a corrosion inhibitor in MEA solutions.

Numerous failures of bourdon tubes in high pressure gauges and transmitters (3000-9000 lb./sq. in.) have been encountered in synthesis gas service. All failures occurred in drawn tubes constructed of low alloy SAE-4130 or 4140 material. Examination of the failed surfaces disclosed that the failures were fatigue and appeared to have originated at fissures in the metal.

Replacement bourdon tubes are now being installed which have been constructed of Type 316 stainless steel. The tubes are bored instead of drawn. Type 316 stainless was chosen because it is less liable to have fissures as encountered in the SAE 4130 or 4140 material. Bored tubes are considered superior to drawn tubes, since the bore can be made smoother, the wall thickness is more uniform, and stresses due to drawing are not present. These features make the bored tube less liable to a fatigue failure than the drawn tube. Again, the bored Type 316 stainless steel tubes have not been in service for a long-enough period of time to evaluate their worth.

A number of leaks have been encountered in ammonium nitrate storage tanks. The tanks are constructed of carbon steel clad plate. The cladding is 1/16 in. thick, Type 321 stainless steel. Nitrate of 80-92% strength is normally stored in these tanks. The leaks in the tank shells, in several instances, were serious enough to necessitate lowering the levels of the tank and making a temporary, bolted or patch, repair.

After one of the tanks was taken out of service and inspected, a number of leaks were found on the bottom. They all occurred at points where lifting lugs had been welded to the plates during construction, and later cut off. Apparently there was some diffusion of carbon steel through the stainless steel cladding. Repairs to the bottom were made by cutting out the affected metal, filling the voids with stainless steel weld metal, and then covering the area with an overlaid stainless steel patch.

The most serious leaks occurred at cracks in welds in the shell of the tank. Inspection revealed that faulty weld practice, during the deposition of the root pass of the carbon steel portion of the weld joint, resulted in a band of carbon steel being deposited on the edge of the stainless steel cladding. As a result, the stainless steel cover pass at this point had inadequate thickness and hot-cracked. The cracks opened to the inner surface and exposed the carbon steel to the hot nitrate. Stress corrosion of the carbon steel shell plates resulted in cracking of the shell plates from the inside out. The leaking ammonium nitrate caused local corrosion of the outer surface metal and promoted stress corrosion cracks, which progressed from the outside of the shell inward. Cracks were discovered which were as much as eight inches long.

Swope King White

A complete inspection was made of all the tank seams by magnetic particle, dye check, and radiographic methods. All cracked areas and areas of suspected faulty welding were cut out. Inlaid patches of stainless steel clad material were welded in place. The entire inner surface of the tank was checked with $CuSO_4$ solution to determine if any carbon steel was present.

Failure of the yoke bushing in a drain valve in NH_3 service recently necessitated shutdown of all three synthesis loops. Inspection of the valve revealed the yoke bushing was made of brass. Galvanic action between the yoke bushing and the carbon steel bonnet caused the carbon threads to deteriorate. Consequently, the stem and threads lifted and the valve could not be shut off.

Inspection of all valves in NH_3 service throughout the unit disclosed that a number with brass yoke sleeves, yoke bushings, and brass packing glands had inadvertently been installed. Even though the brass in the valve that failed appeared to be in good condition, it was decided to replace all brass with either carbon or stainless steel to prevent galvanic action and also to prevent corrosion due to direct contact of ammonia with brass, as is possible in the case of the packing glands.

Several high pressure valve stems (9000 lb./sq. in.) were found to be broken in service, and many others were broken on disassembly of the valves at a recent shutdown. The valve stems were originally made of manganese, non-deforming tool steel, heat treated to 50-55 Rockwell "C." The stems were frozen in and had to be sledged to remove them, causing most of the breakage.

To alleviate this situation, several stems are being constructed of different materials; materials which are more ductile, therefore, more able to withstand shock. One material being tested is a high-carbon, high-chrome tool steel. It is being hardened to 61-62 Rockwell "C" and will be tempered at 775-800°F. The other material is tungsten-alloy chisel and punched steel, similar to the original steel, but is higher in chrome and tungsten. This material is being hardened to 50-55 Rockwell "C."

Molybdenum disulfide will also be used on the stem threads to help prevent them from becoming frozen, thereby eliminating the necessity of sledging them.

MASON, Dow: We had a gauge accident at Midland which might be of interest. It was standard practice to check the pressure on returned oxygen and argon cylinders. If the pressure was high, we assumed that the gas in them need not be removed from the cylinder. On oxygen cylinders we exclusively used an oxygen cylinder gauge made up especially for the purpose. One day this gauge assembly happened to be unusable. The operator used a gauge assembly that had been prepared for argon. The fittings for some argon cylinders were the same as for oxygen, although the standards are being changed and argon cylinders are being converted to a different type of fitting. The gauge was put on and the operator opened the valve to test the pressure. The gauge exploded. The operator was wearing safety glasses and leather gloves which limited the injuries to slight burns on the hands and minor damage to his face, nothing serious.

* SAFETY ROUNDTABLE

Since the frangible discs on the valve were ruptured, we couldn't get reliable analyses of the gas inside the cylinder previous to the explosion. Thus, we could not determine definitely whether or not this gas had been explosive.

The assembly had been made up using Pipe-tite, a pipe stick dope. We found that this material would actually burn in air. Needless to say we are not using it any more. We are now using Key Absolute Sealing Material. The face and part of the Bourdon tube definitely show evidence of heat and they were probably the source of the sparks that were reported as the cylinder was depressuring.

CHAIRMAN WALTON: We have had four pressure gauge failures, all in hydrogen or synthesis gas service. In every case it was a failure of the Bourdon tubes. The pressure gauges were provided with two blowout plugs in the case, but these plugs did not do what they were supposed to do. The whole gauge shattered at the time of the explosion and flew all around the place. As a result, we have adopted a new standard for pressure gauges for 400 lb.-and higher service. We have gone to the Maxi-safe type gauge—a so-called turret case, a steel case with a complete blowout back. A particular example of this type gauge is the Ashcroft Maxi-Safe Duraguage type 1379, with a 316 stainless steel tube, and socket with bottom connection. The case is a steel casting and the whole back "relieves," or blows out, in case of a failure. Since we used these gauges, we have had no gauge failures. We also use plexiglass instead of glass in the front of the gauges. Metallurgical examination showed there was poor grain structure in the Bourdon tubes that failed. In some cases it was thought to be due to notch-type failure, caused by insufficient finishing of the interior of the Bourdon. One of the items asked for was cold-service relief valves. We use 304 or 316 material in the valve, or brass, as the case may be. In the ammonia system, of coure, we use stainless steel almost entirely.

We have found no evidence of hydrogen embrittlement in any of our piping. The hottest location that we examined was the discharge pipe from the final stage of the synthesis compressor. We cut out a piece of that pipe and checked it with bend tests and so on, and it was completely ductile. The operating temperature had been about 330°F, at about 400-lb. pressure. Over a period of about five years there was no evidence of hydrogen embrittlement.

The converter shell has a liner of 11½-13 chrome and a washer sample was cut of that to check for nitriding and grain structure. That showed no change from its original structure. We debated as to what we should do in the way of proof-testing the high pressure vessels, the converter, the high pressure separator, and oil filter. We finally decided that since the interior looked so good, and that the washer sample cut out of the liner also looked good, that we would not subject it to a hydrostatic test at that time, although probably in another five years we feel that we will need to give a proof test to it, to the separator and to the oil filter.

JONES C.I.L.: Are your vessels forgings, or of laminated construction?

CHAIRMAN WALTON: Multilayer A. O. Smith type construction.

JONES, C.I.L.: You should be safe there. I think the main hazard in hydrostatic testing would arise with thick wall forgings, especially those containing side entry ports, or other stress-raising features. This is a case in which it is highly desirable to use warm water for hydrostatic testing. A thick wall forging may be notch brittle at temperatures as high as plus 70°F. I think that a company manufacturing ammonia had a brittle failure some years ago, when hydrostatically testing a converter forging. The fracture originated at a small crack caused by an electrical short circuit—the grounding of one of the starting heater electrodes to the vessel shell at the point of entry due to failure of the electrical insulation. The failure was certainly brittle, the converter shell shattered and fell apart. I don't think this is at all likely with either A. O. Smith type construction or strip wound vessels, and it would be just a question of convenience to test hydrostatically. Water above 70°F would be desirable for thick wall forgings.

CHAIRMAN WALTON: There were a number of tank failures a few years ago that were thought to have been caused by the use of very cold water in hydrostatic testing.

MASON, Dow: I would like to ask about the experience of this group in hydraulic testing of the high pressure cylinder storage for oxygen, nitrogen, or argon, that is, tube bank storage similar to the semitrailers used for transportation of these gases at high pressure. I believe the Interstate Commerce Commission recommends five year frequency for such hydraulic testing of this transporting equipment and I wondered: first, what is the consensus here as to how frequently this hydraulic testing should be done on stationary storage and second, if anyone had any experience in doing this without taking the horizontal tubes out of the rack. This gets to be quite a problem when you have 40 or 50 of these tubes to test.

One other question: What is the recommended frequency of changing the frangible discs in oxygen, argon, and nitrogen cylinders? Has anyone decided to go through an annual replacement of these discs? Has anyone had difficulty from their fatigue and breaking at a time when the pressure is less than the normal test pressure?

SWOPE, Southern Oxygen: The regulations are quite clear as to what must be done in maintaining storage tubes when they are in transit. The ICC regulations stipulate they must be tested every five years. If they are fixed tubes, not in transit, and you are using them for storage, the ICC would not have jurisdiction. The local authority will recognize them as long as they are used and maintained in accordance with the ICC regulations. On the other hand, if you are using ASME containers as fixed storage vessels, no retest would be required. At the present time it's possible to purchase tubes that are stamped with both ICC and ASME markings. If you desire to use them as ASME containers, you must conform to the lower pressure limits permitted under the ASME code. However, the same tube may be used for higher pressures providing you maintain it as an ICC tube.

As to the method of testing, in general, you would have to remove the tube from any rack in which it was mounted because the ICC test requires a water jacket test. The ICC recognizes other test procedures, but, in general, they are not too satisfactory.

Regarding replacement of safety devices, I don't know that anyone has a standard procedure. We do not. We have no fixed replacement schedule as far as cylinders and storage vessels of this sort are concerned. The frequency of their pressure cycling would really be the determining factor.

CHAIRMAN WALTON: Mr. King, you spoke on this subject before and, as I recall, your feeling was for annual inspection. Have you changed your thoughts any since then?

KING, Sohio: Due to a variety of reasons we are having inspection this fall. We'll metal-inspect the major portion of the processing equipment. In particular, we will inspect the points where we may have had some high temperature operation at the converter outlet.

As to hydrostatic testing, we did retest the converter effluent coolers but only at operating pressures. We applied a formula.

CHAIRMAN WALTON: Has anyone else removed a set of internals in service five years or more, getting nitriding data on them?

WHITE, San Jacinto: If you are interested in anything less than five years, we recently had some converters made at 321 stainless. After a very short time they were very badly nitrided, in fact, they failed. It looks to us that at any temperature over 625°C, the nitriding is extensive, so we now operate considerably under that, and we are trying some 347 stainless on our next converter. We made some tests and found that 46 chrome comes out better than any of the stainless steels we were able to find. #

for fluid mechanics heat transfer, mass transfer and chemical reaction

Dimensionless numbers

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Use of dimensionless numbers or groups of variables in the various branches of engineering is expanding at a rapid pace. The number of such groups is becoming so large that recollection of their definitions and significance imposes a burden on the memory. Accordingly, we have drawn up a list, presented in the following Table, of dimensionless numbers now in use in fields of interest to chemical engineers. The list provides the name, formula, significance, area of use, and source references for each of these numbers. In addition to serving as a ready reference for the meaning of such numbers, this tabulation is expected to assist in proper labelling of coefficients in non-dimensionalized differential equations, and to facilitate proper selection of groupings that arise in model and scale-up studies.

In connection with model and scale-up studies, if all the variables affecting a particular operation are known, dimensional analysis can be employed to indicate the groups of variables that are significant. The number of experiments needed in a model study is thus reduced by dimensional analysis, since only the effect of each grouping need be explored rather than the effect of each individual variable.

The principle of similarity must be observed in the planning of model studies. Four types of similarities are important in most chemical engineering studies; namely,

1. Geometric similarity (dimensional proportionality)
2. Mechanical similarity
   a. Static similarity (deformation proportionality)
   b. Kinematic similarity (time proportionality)
   c. Dynamic similarity (force proportionality).
3. Thermal similarity (temperature proportionality)
4. Chemical similarity (concentration proportionality)

Selection of dimensions and operating conditions so as to satisfy the geometric, thermal, and chemical similarity requirements is usually relatively straightforward. Satisfaction of the mechanical-similarity requirements, however, generally involves proportionality control of certain critical groups of variables that are selected either by dimensional analysis, as mentioned earlier, or by inspection. The latter procedure, in particular, requires familiarity with known dimensionless numbers and their significance.

A detailed discussion of the use of dimensionless numbers is beyond the scope of this article. However, a number of excellent treatments of this subject can be found in the literature; for example, see References 5, 19, 27, 35, and 36.

SOURCE REFERENCES

1. Badger, W. L., *Trans. Am. Inst. Chem. Engrs.*, *33*, 441 (1937).
2. Benton, G. S., *J. Appl. Mech.*, *23*, 123 (1956).
3. Berman, K., *J. Appl. Mech.*, *22*, 197 (1955).
4. Bernard, R. A., and Wilhelm, R. H., *Chem. Eng. Progr.*, *46*, No. 5, 233 (1950).
5. Boelter, L. M. K., Cherry, V. H., Johnson, H. A., and Martinelli, R. C., *Heat Transfer Notes*, Berkeley and Los Angeles, University of California Press, 1946.
6. Bonilla, C. F., *Ind. Eng. Chem.*, *31*, 618 (1939).
7. Broer, L. J. F., *Appl. Sci. Res.*, *A6*, No. 2-3, 226 (1956).

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Turn to the next nine pages for complete table of numbers

DIMENSIONLESS GROUPINGS AND THEIR SIGNIFICANCE

Name	Symbol	Formula	Special Nomenclature[1]	Proportional to:[2]	Where Used and Reference
FLUID MECHANICS					
Alfven Number		V_A/V	V_A = velocity of Alfven magnetic wave, $[L/\theta]$	$\frac{\text{Velocity of Alfven wave}}{\text{Velocity of fluid}}$; $= S^{1/2}$	Magneto fluid dynamics, 11
Bingham Number	N_{Bm}	$\tau_y g_c L/\mu_p V$	L = width of channel, $[L]$ μ_p = coeff. of rigidity, $[M/\theta L]$ τ_y = yield stress, $[F/L^2]$	$\frac{\text{Yield stress}}{\text{Viscous stress}}$	Flow of Bingham plastics, 43
Bond Number	N_{Bo}	$(\rho-\rho')L^2 g_L/g_c\sigma$	L = diam. of droplet, $[L]$ ρ = density of droplet, $[M/L^3]$ ρ' = density of surrounding fluid, $[M/L^3]$ σ = surface tension, $[F/L]$	$\frac{\text{Gravitational force}}{\text{Surface-tension force}}$	Atomization, 46
Cauchy Number	N_c	$\rho V^2/g_c E_b$	E_b = bulk modulus of fluid, $[F/L^2]$	$\frac{\text{Inertial force}}{\text{Compressibility force}}$; $= (N_{Ma})^2$	Compressible flow, 35, 48
Cavitation Number	σ_c	$[(p-p_v)/\rho](V^2/2g_c)$	p = local absolute static pressure, $[F/L^2]$ p_v = vapor pressure, $[F/L^2]$	$\frac{\text{Excess of local static head over vapor-pressure head}}{\text{Velocity head}}$	Cavitation, 23
Crocco Number	N_{Cr}	V/V_{max}	$V_{max.}$ = maximum possible velocity of gas expanding adiabatically, $[L/\theta]$ γ = ratio of specific heats, dimensionless	$\frac{\text{Velocity}}{\text{Maximum velocity}}$; $=\left(1+\frac{2}{(\gamma-1)(N_{Ma})^2}\right)^{-1/2}$	Compressible flow, 25
Dean Number[3]	N_D	$(VL\rho/\mu)(L/2R)^{1/2}$	L = diam. of pipe, $[L]$ R = radius of curvature, $[L]$	$= N_{Re}(L/2R)^{1/2}$	Flow in curved channels, 52
Drag Coefficient	C_d	$(\rho-\rho')Lg_L/\rho V^2$	L = characteristic dimension of object, $[L]$ ρ = density of object, $[M/L^3]$ ρ' = density of surrounding fluid, $[M/L^3]$	$\frac{\text{Gravitational force}}{\text{Inertial force}}$	Free settling velocities, 41
Eckert Number	N_E			$=2/N_{rf}$	Compressible flow, 52
Elasticity Number	N_{El}	$\theta_r\mu/\rho L^2$	L = radius of pipe $[L]$ θ_r = relaxation time, $[\theta]$	$\frac{\text{Elastic force}}{\text{Inertial force}}$	Viscoelastic flow, 7
Euler Number[4,5a]	N_{Eu}	$g_c(\Delta p_F/\rho)/V^2$	N = number of velocity heads, dimensionless $\Delta p_F/\rho$ = friction head, $[LF/M]$	$\frac{\text{Friction head}}{2 \times \text{Velocity head}}$; $= N/2$	Fluid friction in conduits, 19, 22, 36

(1) See General Nomenclature on page 64.
(2) See Force Proportionalities on page 64.

(3) The Dean number and the Taylor number (page 59) are identical. The Dean number characterizes the double-eddy effect in the curved channel and the Taylor number characterizes the stability of the Taylor vortices in the annulus.

(4) This Euler number and the Power number (page 58) are special forms of the Newton Inertial Force Group. The number of velocity heads is twice the Newton Inertial Force Group.
(5a) This Euler number is used in the chemical engineering literature.

DIMENSIONLESS GROUPINGS (continued)

Name	Symbol	Formula	Special Nomenclature[1]	Proportional to:[2]	Where Used and Reference
Euler Number[5a]	N_{Eu}	$g_c D(-dp/dL)/\rho V^2$	D = diam. of round pipe, $[L]$ dp/dL = pressure gradient, $[F/L^3]$	$= 2f$	Fluid friction in conduits, 5, 47
Fanning Friction Factor	f	$g_c D(\Delta p_F/\rho)/2V^2L$	D = characteristic diam. of cross section, $[L]$ L = length of pipe, $[L]$ $\Delta p_F/\rho$ = friction head, $[LF/M]$	Shear stress at pipe wall expressed as number of velocity heads	Fluid friction in conduits, 40
Froude Number	N_{Fr}	$V^2/g_L L$	L = characteristic dimension of system, $[L]$	$\dfrac{\text{Inertial force}}{\text{Gravitational force}}$	Wave and surface behavior, 19, 48
Galileo Number	N_{Ga}	$L^3 g_L \rho^2/\mu^2$	L = characteristic dimension of system, $[L]$	$(N_{Re})\left(\dfrac{\text{Gravitational force}}{\text{Viscous force}}\right)$	Circulation in baths of viscous liquids, 26
Hartmann Number	M_H	$(\mu_e^2 H_e^2 \sigma_e L^2/\mu)^{1/2}$	H_e = field strength, $[Q/L\theta]$ L = thickness of fluid layer, $[L]$ μ_e = magnetic permeability, $[ML/Q^2]$ σ_e = electrical conductivity, $[Q^2\theta/L^3M]$	$\dfrac{\text{Magnetically induced stress}}{\text{Hydrodynamic shear stress}}$; $= (SR_M N_{Re})^{1/2}$	Magneto fluid dynamics, 11, 12
Hedström Number	N_{He}	$\tau_y L^2 \rho g_c/\mu_p^2$	L = characteristic dimension of system, $[L]$ μ_p = coeff. of rigidity, $[M/\theta L]$ τ_y = yield stress, $[F/L^2]$	$= (N_{Re})(N_{Bm})$	Flow of Bingham plastics, 32
Hodgson Number	N_H	$V'f'\Delta p_F/\bar{q}\,\bar{p}$	f' = frequency, $[1/\theta]$ $\bar{p}$ = average static pressure, $[F/L^2]$ Δp_F = pressure drop due to friction, $[F/L^2]$ $\bar{q}$ = average volumetric flow rate, $[L^3/\theta]$ V' = volume of system, $[L^3]$	$\dfrac{\text{Time constant of system}}{\text{Period of pulsation}}$	Pulsating gas flow, 37
Karman Number	N_K	$g_c \rho D^3(-dp/dL)/\mu^2$	D = diam. of round pipe, $[L]$ dp/dL = pressure gradient, $[F/L^3]$	$= 2(N_{Re}\sqrt{f})^2$	Fluid friction in conduits, 6, 47
Knudsen Number	N_{Kn}	λ/L	L = characteristic dimension of system, $[L]$ λ = length of mean free path, $[L]$	$\dfrac{\text{Length of mean free path}}{\text{Characteristic dimension of system}}$	Flow of gases at low pressures, 14

[1] See General Nomenclature on page 64.

[2] See Force Proportionalities on page 64.

[5a] This Euler number is used in the mechanical engineering literature.

DIMENSIONLESS GROUPINGS (continued)

Name	Symbol	Formula	Special Nomenclature[1]	Proportional to:[2]	Where Used and Reference
Mach Number	N_{Ma}	V/V_c	V_c = velocity of sound in fluid, $[L/\theta]$	$\frac{\text{Linear velocity}}{\text{Velocity of sound}}; = (N_c)^{1/2}$	Compressible flow, 35, 57
Magnetic Pressure Number	S	$\mu_e H_e^2/\rho V^2$	H_e = field strength, $[Q/L\theta]$ μ_e = magnetic permeability, $[ML/Q^2]$	$\frac{\text{Magnetic pressure}}{2 \times \text{Dynamic pressure}}$	Magneto fluid dynamics, 11, 12, 38, 39
Magnetic Reynolds Number	R_M	$\sigma_e \mu_e L V$	L = characteristic dimension of system, $[L]$ μ_e = magnetic permeability, $[ML/Q^2]$ σ_e = electrical conductivity, $[Q^2\theta/L^3M]$	$\frac{\text{Mass transport diffusivity}}{\text{Magnetic diffusivity}}; = R_V$	Magneto fluid dynamics, 11, 12
Newton Inertial Force Group[4]	N_I	$Fg_c/\rho V^2L^2$	F = force, $[F]$ L = characteristic dimension of system, $[L]$	$\frac{\text{Imposed force}}{\text{Inertial force}}$	Agitation, 49
Number of Velocity Heads[4]	N	$(F/\rho L^2)/(V^2/2g_c)$	F = force, $[F]$ L = characteristic dimension of system, $[L]$	$\frac{\text{Imposed head}}{\text{Velocity head}}$	Fluid friction in conduits, 29, 30
Ohnesorge Number	Z	$\mu/(\rho g_c L\sigma)^{1/2}$	L = characteristic dimension of system, $[L]$ σ = surface tension, $[F/L]$	$\frac{\text{Viscous force}}{(\text{Inertial force} \times \text{Surface-tension force})^{1/2}}; = \frac{(N_{We})^{1/2}}{N_{Re}}$	Atomization, 33
Pipeline Parameter	ρ_n	$aV_o/2g_cH$	a = water-hammer wave velocity, $[L/\theta]$ H = static head, $[LF/M]$ V_o = initial velocity, $[L/\theta]$	$\frac{\text{Maximum water-hammer pressure rise}}{2 \times \text{Static pressure}}$	Water hammer, 45 (hydraulic transients)
Poiseuille Number		$g_cD^2(-dp/dL)/\mu V$	D = diameter of round pipe, $[L]$ dp/dL = pressure gradient, $[F/L^3]$	= 32	Laminar fluid friction, 47
Power Number[4]	N_p	$Pg_c/L^5\rho n^3$	P = power to agitator, $[LF/\theta]$ L = characteristic dimension of agitator paddle, $[L]$ n = rate of rotation, $[1/\theta]$	$\frac{\text{Drag force on paddle}}{\text{Inertial force}}$	Power consumption in agitated vessels, 50
Prandtl Velocity Ratio	u^+	$u/(\tau_w g_c/\rho)^{1/2}$	u = local velocity, $[L/\theta]$ τ_w = shear stress at wall, $[F/L^2]$	$\left(\frac{\text{Inertial force}}{\text{Wall shear force}}\right)^{1/2}; = \frac{u}{V}\left(\frac{f}{2}\right)^{1/2}$	Turbulence, 24, 54

(1) See General Nomenclature on page 64.

(2) See Force Proportionalities on page 64.

(4) The Euler number (page 56) and Power number are special forms of the Newton Inertial Force Group. The number of velocity heads is twice the Newton Inertial Force Group.

DIMENSIONLESS GROUPINGS (continued)

Name	Symbol	Formula	Special Nomenclature[1]	Proportional to:[2]	Where Used and Reference
Ratio of Specific Heats	γ	c_p/c_v	c_p = specific heat at constant pressure, $[H/MT]$ c_V = specific heat at constant volume, $[H/MT]$	$\frac{\text{Specific heat at constant pressure}}{\text{Specific heat at constant volume}}$	Compressible flow, 28
Rayleigh Number				$= (N_{We})^{1/2}$	Breakup of liquid jets, 46
Reynolds Number	N_{Re}	$LV\rho/\mu$	L = characteristic dimension of the system, $[L]$	$\frac{\text{Inertial force}}{\text{Viscous force}}$; For gases, $\propto N_{Ma}/N_{Kn}$	Dynamic similarity, 22, 48, 57
Richardson Number	N_{Ri}	$-(g_L/\rho)(d\rho/dL)/(dV/dL)^2$	L = height of layer, $[L]$	$\frac{\text{Gravity force}}{\text{Inertial force}}$	Stratified flow of multiliquid system, 44, 52
Rossby Number	N_{Ro}	$V/2\omega L \sin\alpha$	L = characteristic dimension of the system, $[L]$ α = angle between axis of earth's rotation and direction of fluid motion, dimensionless ω = angular velocity of earth's rotation, $[1/\theta]$	$\frac{\text{Inertial force}}{\text{Coriolis force}}$	Effect of earth's rotation on flow in pipes, 2
Roughness Factor		ϵ/L	L = characteristic diameter of cross section of channel, $[L]$ ϵ = height of roughness, $[L]$	$\frac{\text{Height of roughness}}{\text{Diameter of channel}}$	Fluid friction, 34
Sommerfeld Number	N_S	$(\mu n/g_c p)(D/c)^2$	c = clearance or annulus width, $[L]$ D = diam. of shaft, $[L]$ p = pressure on bearing, $[F/L^2]$ n = rotational speed of shaft, $[1/\theta]$	$\frac{\text{Viscous force}}{\text{Load force}}$	Lubrication, 15
Strouhal Number	N_{St}	$f'L/V$	f' = frequency, $[1/\theta]$ L = characteristic dimensional of obstacle, $[L]$	Reciprocal of vortex spacing expressed as number of obstacle diameters	von Karman vortex streets, 47, 55
Taylor Number[3]	N_{Ta}	$\omega r_a^{1/2} b^{3/2} \rho/\mu$	b = width of annulus, $[L]$ r_a = mean radius of annulus, $[L]$ ω = angular velocity of cylinder, $[1/\theta]$		Stability of flow pattern in annulus with a rotating cylinder, 20

(1) See General Nomenclature on page 64.

(2) See Force Proportionalities on page 64.

(3) The Dean number (page 56) and the Taylor number are identical. The Dean number characterizes the double-eddy effect in the curved channel and the Taylor number characterizes the stability of the Taylor vortices in the annulus.

DIMENSIONLESS GROUPINGS (continued)

Name	Symbol	Formula	Special Nomenclature[1]	Proportional to:[2]	Where Used and Reference
Thoma Number	σ_T	$(H_a - H_S - H_V)/H$	H = total head, $[LF/M]$ H_a = atmospheric-pressure head, $[LF/M]$ H_S = suction head, $[LF/M]$ H_V = vapor-pressure head, $[LF/M]$	$\dfrac{\text{Net positive suction head}}{\text{Total head}}$	Cavitation in pumps, 48, 56
Velocity Number	R_V			$\dfrac{\text{Velocity of fluid}}{\text{Velocity of magnetic field}}; \quad = R_M$	Magneto fluid dynamics, 38, 39
Weber Number	N_{We}	$V^2\rho L/g_c\sigma$	L = characteristic dimension of system, $[L]$ σ = surface tension, $[F/L]$	$\dfrac{\text{Inertial force}}{\text{Surface-tension force}}$	Bubble formation, breakup of liquid jet, 35, 48
HEAT TRANSFER					
Biot Number	N_{Bi}	hr_m/k	r_m = distance from midpoint to surface, $[L]$	$\dfrac{\text{Midplane thermal internal resistance}}{\text{Surface film resistance}}$	Unsteady-state heat conduction, 5, 22, 31
Condensation Number	N_{Co}	$(h/k)(\mu^2/\rho^2 g_L)^{1/3}$		$(N_{Nu})\left[\left(\dfrac{\text{Viscous force}}{\text{Gravitational force}}\right)\left(\dfrac{1}{N_{Re}}\right)\right]^{1/3}$	Condensation, 1, 21, 31
Condensation Number	N_{Cv}	$(L^3\rho^2 g_L\lambda/k\mu\Delta t)$	L = characteristic height of system, $[L]$ Δt = temperature difference across film, $[T]$ λ = latent heat of condensation, $[H/M]$	$(N_{Re})(N_{Pr})\left(\dfrac{\text{Gravitational force}}{\text{Viscous force}}\right)\left(\dfrac{\text{Latent heat}}{\text{Sensible heat}}\right)$	Condensation on vertical walls 22, 58
Fourier Number	N_{Fo}	$k\theta/\rho c_p r_m^2$	r_m = distance from midpoint to surface, $[L]$ θ = elapsed time, $[\theta]$	Elapsed time / Time required to bring solid to final temperature based on steady-state heat transfer with a temperature difference equal to initial unsteady-state temperature difference	Unsteady-state heat conduction, 16, 22, 31
Graetz Number	N_{Gz}	wc_p/kL	L = length of heat-transfer channel, $[L]$ w = mass rate of flow, $[M/\theta]$	$\dfrac{\text{Thermal capacity of fluid}}{\text{Conductive heat transfer}}$	Streamline flow, 10, 22, 31
Grashof Number	N_{Gr}	$L^3\rho^2 g_L\beta\Delta t/\mu^2$	L = height of surface, $[L]$ Δt = temperature difference across film, $[T]$ β = coefficient of expansion, $[1/T]$	$(N_{Re})\left(\dfrac{\text{Buoyancy force}}{\text{Viscous force}}\right); \quad = (N_{Ga})\beta\Delta t$	Free convection, 10, 22
J-Factor for Heat Transfer	j_H	$(h/c_pG)(c_p\mu/k)^{2/3}$	G = mass velocity, $[M/\theta L^2]$	$= (N_{Nu})/(N_{Re})(N_{Pr})^{1/3}$	Heat, mass, and momentum transfer analogy, 10, 31

(1) See General Nomenclature on page 64. (2) See Force Proportionalities on page 64.

DIMENSIONLESS GROUPINGS (continued)

Name	Symbol	Formula	Special Nomenclature[1]	Proportional to:[2]	Where Used and Reference
McAdams Group		$h^4 L \mu \Delta t / k^3 \rho^2 g_L \lambda$	L = characteristic length of system, $[L]$; Δt = temperature difference across film, $[T]$; λ = latent heat of condensation, $[H/M]$	A constant depending upon the orientation of the surface	Condensation, 19
Nusselt Number	N_{Nu}	hL/k	L = characteristic length of heat-transfer path, $[L]$	$\frac{\text{Total heat transfer}}{\text{Conductive heat transfer}}$; $= (N_{Pe})(N_{St})$	Forced convection, 10, 22, 31
Peclet Number	N_{Pe}	$LV\rho c_p/k = LV/\alpha$	L = characteristic dimension of system, $[L]$; α = thermal diffusivity, $[L^2/\theta]$	$\frac{\text{Bulk transport of heat}}{\text{Conductive heat transfer}}$; $= (N_{Re})(N_{Pr})$	Forced convection, 10, 22, 31
Prandtl Number	N_{Pr}	$c_p \mu / k$		$\frac{\text{Kinematic Viscosity}}{\text{Thermal diffusivity}}$; $\frac{\text{Momentum diffusivity}}{\text{Thermal diffusivity}}$	Forced convection, free convection, 10, 22, 31
Rayleigh Number[6]	R'			$= (N_{Gr})(N_{Pr})$	Free convection, 12, 13
Recovery Factor	N_{rf}	$c_p(t_{aw} - t_m)/(V^2/2g_c J)$	J = mechanical equivalent of heat, $[LF/H]$; t_{aw} = attained adiabatic wall temperature, $[T]$; t_m = moving stream temperature, $[T]$	$\frac{\text{Actual temperature recovery}}{\text{Theoretical temperature recovery}}$; $= \frac{2}{N_E}$	Convective heat transfer in compressible flow, 31
Stanton Number	N_{St}	$h/c_p \rho V = h/c_p G$	G = mass velocity, $[M/\theta L^2]$	$\frac{\text{Heat actually transferred}}{\text{Thermal capacity of fluid}}$; $= \frac{(N_{Nu})}{(N_{Re})(N_{Pr})}$	Forced convection, 10, 22, 31
Thring's Radiation Group		$\rho c_p V / \epsilon s T^3$	s = Stefan-Boltzmann constant, $[H/L^2 T^4 \theta]$; T = absolute temperature of surface, $[T]$; ϵ = emissivity of surface, dimensionless	$\frac{\text{Bulk transport of heat}}{\text{Heat transferred by radiation}}$	Radiation, 19
MASS TRANSFER					
Colburn Group		(See Schmidt Number)			19
J-Factor for Mass Transfer	j_M	$(k_c \rho / G)(\mu / \rho D_v)^{2/3}$	D_v = molecular diffusivity, $[L^2/\theta]$; G = mass velocity, $[M/\theta L^2]$; k_c = mass transfer coefficient, $[L/\theta]$	$= (k_c \rho / G)(N_{Sc})^{2/3}$	Mass, heat, and momentum transfer analogy, 9, 10, 53

(1) See General Nomenclature on page 64.

(2) See Force Proportionalities on page 64.

(6) This number is not in common use. The name Rayleigh is generally associated with the number shown under Fluid Mechanics.

DIMENSIONLESS GROUPINGS (continued)

Name	Symbol	Formula	Special Nomenclature[1]	Proportional to:[2]	Where Used and Reference
Lewis Number	N_{Le}	$k/\rho c_p D_V = \alpha/D_V$	D_V = molecular diffusivity, $[L^2/\theta]$ α = thermal diffusivity, $[L^2/\theta]$	$\frac{\text{Thermal diffusivity}}{\text{Molecular diffusivity}}$; $= N_{Sc}/N_{Pr}$	Mass and heat transfer, 22
Merkel Number	N_{Me}	$k_m a V'/w_G$	a = area cooling surface per unit volume, $[1/L]$ k_m = mass transfer coefficient, $[M/\theta L^2]$ V' = gross volume, $[L^3]$ w_G = mass flow rate of gas, $[M/\theta]$	$\frac{\text{Mass of water transferred in cooling per unit humidity difference}}{\text{Mass of dry air}}$	Direct contact of liquid and gas, cooling towers, 18
Peclet Number	N_{Pe}'	LV/D'	D' = characteristic diffusion coefficient, $[L^2/\theta]$ L = characteristic length, $[L]$	$\frac{\text{Bulk mass transport}}{\text{Diffusive mass transport}}$	Diffusion in packed beds, 4, 8
Psychrometric Ratio		$h_c/k_m s'$	h_c = convective heat transfer coefficient, $[H/\theta L^2 T]$ k_m = mass transfer coefficient, $[M/\theta L^2]$ s' = humid heat, $[H/MT]$	$\frac{\text{Heat transferred by convection}}{\text{Heat transferred by mass transfer}}$	Wet- and dry-bulb thermometry, 58
Schmidt Number	N_{Sc}	$\mu/\rho D_v$	D_v = molecular diffusivity, $[L^2/\theta]$	$\frac{\text{Kinematic viscosity}}{\text{Molecular diffusivity}}$, $\frac{\text{Momentum diffusivity}}{\text{Molecular diffusivity}}$	Dynamic similarity 10, 22, 31, 53
Sherwood Number[7]	N_{Sh}	$k_c L/D_v$	D_v = molecular diffusivity, $[L^2/\theta]$ k_c = mass transfer coefficient, $[L/\theta]$ L = characteristic dimension of system, $[L]$	$\frac{\text{Mass diffusivity}}{\text{Molecular diffusivity}}$	Dynamic similarity, 42, 51
Taylor Number[7]		(See Sherwood Number)			3
CHEMICAL REACTION					
Arrhenius Group		E/RT	E = activation energy, $[LF/M]$ R = gas constant, $[LF/MT]$ T = absolute temperature, $[T]$	$\frac{\text{Activation energy}}{\text{Potential energy of fluid}}$	Reaction rate, 19

(1) See General Nomenclature on page 64.

(2) See Force Proportionalities on page 64.

(7) The Sherwood number is preferred. The name Taylor probably should be reserved more properly for the number shown under Fluid Mechanics.

DIMENSIONLESS GROUPINGS (continued)

Name	Symbol	Formula	Special Nomenclature[1]	Proportional to:[2]	Where Used and Reference
Damköhler[3] Group I		UL/Vc_A	c_A = concentration, $[M/L^3]$ k' = reaction rate constant, $[(1/\theta)(L^3/M)^{n-1}]$ L = characteristic dimension of system, $[L]$ n = reaction order, dimensionless U = reaction rate, $[M/L^3\theta]$ θ = time, $[\theta]$	$\dfrac{\text{Chemical reaction rate}}{\text{Bulk mass flow rate}}$; $= k'\theta c_A^{n-1}$, reaction rate time constant for n^{th} order reaction	Combined chemical reaction, momentum transfer, and heat transfer, 19, 59
Damköhler[3] Group II		$UL^2/D_V c_A$	c_A = concentration, $[M/L^3]$ D_V = molecular diffusivity, $[L^2/\theta]$ k' = reaction rate constant, $[(1/\theta)(L^3/M)^{n-1}]$ L = characteristic dimension of system, $[L]$ n = reaction order, dimensionless U = reaction rate, $[M/L^3\theta]$	$\dfrac{\text{Chemical reaction rate}}{\text{Molecular diffusion rate}}$; $= \dfrac{L^2(k'c_A^{n-1})}{D_v}$	Combined chemical reaction, momentum transfer, and heat transfer, 19, 59
Damköhler[3] Group III		$QUL/c_p\rho Vt$	L = characteristic dimension of system, $[L]$ Q = heat generated, $[H/M]$ t = temperature, $[T]$ U = reaction rate, $[M/L^3\theta]$	$\dfrac{\text{Heat liberated}}{\text{Bulk transport of heat}}$	Combined chemical reaction, momentum transfer, and heat transfer, 19, 59
Damköhler[3] Group IV		QUL^2/kt	L = characteristic dimension of system, $[L]$ Q = heat generated, $[H/M]$ t = temperature, $[T]$ U = reaction rate, $[M/L^3\theta]$	$\dfrac{\text{Heat liberated}}{\text{Conductive heat transfer}}$	Combined chemical reaction, momentum transfer, and heat transfer, 19, 59
Damköhler[3] Group V		(See Reynolds Number)			19, 59
Guldberg-Waage Group	N_{Gw}	(Defined by an equation relating volumes of reacting gases and reaction products)			Chemical reaction in blast furnaces, 19
Thiele Modulus	m_T			= (Damköhler Group II)$^{1/2}$	Diffusion in porous catalysts, 17

[1] See General Nomenclature on page 64.
[2] See Force Proportionalities on page 64.

[3] The Damköhler groups can be combined to give other known groups as follows:

$$\frac{\text{Group II}}{(\text{Group I})(\text{Group V})} = N_{Sc};\quad \frac{\text{Group IV}}{(\text{Group III})(\text{Group V})} = N_{Pr}$$

Source References

continued

8. Carberry, J. J., *Can. J. Chem. Eng.*, *36*, 207 (1958).
9. Chilton, T. H. and Colburn, A. P., *Ind. Eng. Chem.*, *26*, 1183 (1934).
10. Colburn, A. P., *Trans. Am. Inst. Chem. Engrs.*, *29*, 174 (1933).
11. Covert, E. E., *On Some Fundamentals in Magneto-Fluid-Mechanics*, Technical Report 247, Naval Supersonic Laboratory, Mass. Inst. Tech., March 1958.
12. Cowling, T. G., *Magnetohydrodynamics*, New York, Interscience, 1957.
13. Dunn, W. F., Bonilla, C. F., Ferstenberg, C., and Gross, B., *A.I.Ch.E. Journal*, 2, 184 (1956).
14. Folsom, R. G., *Trans. Am. Soc. Mech. Engrs.*, *74*, 915 (1952).
15. Fuller, D. D., *Theory and Practice of Lubrication for Engineers*, New York, Wiley, 1956.
16. Gurney, H. P., and Lurie, J., *Ind. Eng. Chem.*, *15*, 1170 (1923).
17. Hougen, O. A. and Watson, K. M., *Chemical Process Principles*, New York, Wiley, 1947.
18. Jakob, M., *Heat Transfer*, Vol. II, New York, Wiley, 1957.
19. Johnstone, R. E., and Thring, M. W., *Pilot Plants, Models, and Scale-Up Methods in Chemical Engineering*, New York, McGraw-Hill, 1957.
20. Kaye, J., and Elgar, E. C., "Modes of Adiabatic and Diabatic Fluid Flow in an Annulus Within an Inner Rotating Cylinder," ASME Paper No. 57-HT-14, presented at ASME-AIChE Conference, Aug. 11-15, 1957. University Park, Pa.
21. Kirkbride, C. G., *Trans. Am. Inst. Chem. Engrs.*, *30*, 170 (1933-34).
22. Klinkenberg, A., and Mooy, H. H., *Chem. Eng. Progr.*, *44*, No. 1, 17 (1948).
23. Knapp, R. T., and Hollander, A., *Trans. Am. Soc. Mech. Engrs.*, *70*, 419 (1948).
24. Knudsen, J. G., and Katz, D. L., *Fluid Dynamics and Heat Transfer*, New York, McGraw-Hill, 1958.
25. Korst, H. H., *J. Appl. Mech.*, *23*, 593 (1956).
26. Kruszewski, S., *J. Soc. Glass Tech.*, *41*, 259 (1957).
27. Langhaar, H. L., *Dimensional Analysis and Theory of Models*, New York, Wiley, 1951.
28. Lapple, C. E., *Trans. Am. Inst. Chem. Engrs.*, *39*, 385 (1943).

General Nomenclature

c_p = specific heat, $[H/MT]$
E_b = bulk modulus, $[F/L^2]$
g_L = gravitational constant, $[L/\theta^2]$
g_c = conversion factor, $[LM/F\theta^2]$
h = coefficient of heat transfer, $[H/L^2T\theta]$
k = thermal conductivity, $[H/LT\theta]$
L = characteristic dimension of system, $[L]$
V = fluid velocity, $[L/\theta]$
α = angle, dimensionless
β = coefficient of expansion, $[1/T]$
Δt = temperature difference, $[T]$
θ_r = relaxation time, $[\theta]$
μ = viscosity, $[M/L\theta]$
ρ = density, $[M/L^3]$
σ = surface tension, $[F/L]$
τ_w = shear stress at wall, $[F/L^2]$
ω = angular velocity, $[1/\theta]$

Force Proportionalities

Buoyancy Force $\propto L^3\rho\beta\Delta t g_L/g_c$
Compressibility Force $\propto E_bL^2$
Coriolis Force $\propto 2(\rho/g_c)L^3\omega V \sin\alpha$
Elastic Force $\propto \theta_r\mu V^2$
Gravitational Force $\propto L^3(\rho-\rho')g_L/g_c$
Inertial Force $\propto L^2\rho V^2/g_c$
Surface-Tension Force $\propto L\sigma$
Viscous Force $\propto L\mu V/g_c$
Wall Shear Force $\propto \tau_w L^2$

Dimensions used are:
$[F]$ Force
$[H]$ Heat
$[L]$ Length
$[M]$ Mass
$[Q]$ Electric charge
$[T]$ Temperature
$[\theta]$ Time

29. Lapple, C. E., *Heating, Piping Air Conditioning*, *17*, 179-83, 262-7, 319-24 (1945).
30. Lapple, C. E., *Chem. Eng.*, *56*, No. 5, 96 (1949).
31. McAdams, W. H., *Heat Transmission*, 3rd ed., New York, McGraw-Hill, 1954.
32. Metzner, A. B., "Non-Newtonian Technology," in Drew, T. B. and Hoopes, J. W., *Advances in Chemical Engineering*, Vol. I, New York, Academic Press, 1956.
33. Miesse, C. C., *Ind., Eng. Chem.*, *47*, 1690 (1955).
34. Moody, L. F., *Trans. Am. Soc. Mech. Engrs.*, *66*, 671 (1944).
35. Murphy, G., *Similitude in Engineering*, New York, Ronald Press, 1950.
36. Murphy, N. F., "Dimensional Analysis," *Bulletin of the Virginia Polytechnic Institute*, Engineering Experiment Station Series No. 73, *XLII*, No. 6, Sept. 1949.
37. Oppenheim, A. K., and Chilton, E. G., *Trans. Am. Soc. Mech. Engrs.*, *77*, 231 (1955).
38. Pai, S. I., "Magnetohydrodynamics and Magnetogasdynamics," Tech. Note BN-59, Inst. Fluid Dynamics and Appl. Math., University of Maryland, Sept. 1955.
39. Pai, S. I., *Viscous Flow Theory, II—Turbulent Flow*, Princeton, Van Nostrand, 1957.
40. Perry, J. H., *Chemical Engineers' Handbook*, 3rd ed., New York, McGraw-Hill, 1950, p. 382.
41. Ibid, p. 1018.
42. Pigford, R. L., *Ind. Eng. Chem.*, *46*, 937 (1954).
43. Prager, W., "Finite Plastic Deformation," Ch. 3 in Eirich, F. R., *Rheology Theory and Application*, Vol. I, New York, Academic Press, 1956.
44. Prandtl, L., *Essentials of Fluid Dynamics*, New York, Hafner, 1952.
45. Rich, G. R., *Hydraulic Transients*, New York, McGraw-Hill, 1951.
46. Richardson, E. G., "Liquid Sprays," Ch. VI in Hermans, J. J., *Flow Properties of Disperse Systems*, New York, Interscience, 1953.
47. Rouse, H., *Engineering Hydraulics*, New York, Wiley, 1950.
48. Rouse, H., and Ince, S., *History of Hydraulics*, Iowa City, State University of Iowa, 1957.
49. Rushton, J. H., *Chem. Eng. Progr.*, *48*, No. 1, 33 (1952).
50. Rushton, J. H. and Oldshue, J. Y., *Chem. Eng. Progr.*, *49*, No. 4, 161 (1953).
51. Sage, B. H., *Chem. Eng. Progr.*, *49*, No. 7, 4 (1953).
52. Schlichting, H., *Boundary Layer Theory*, New York, McGraw-Hill, 1955.
53. Sherwood, T. K., and Pigford, R. L., *Absorption and Extraction*, 2nd ed., McGraw-Hill, 1952.
54. Souders, M., *Chem. Eng. Progr.*, *52*, No. 6, 255 (1956).
55. Steinman, D. B., *Am. Scientist*, *42*, 397-438, 460 (1954).
56. Stepanoff, A. J., *Centrifugal and Axial Flow Pumps—Theory, Design, and Applications*, New York, Wiley, 1948.
57. von Karman, T., *Aerodynamics*, Ithaca, Cornell Univ. Press, 1954.
58. Walker, W. H., Lewis, W. K., McAdams, W. H., and Gilliland, E. R., *Principles of Chemical Engineering*, 3rd ed., New York, McGraw-Hill, 1937.
59. Way, S., "Combustion in the Turbojet Engine," in *Selected Combustion Problems—II*, AGARD, London, Butterworth's Scientific Publications, 1956.

Part two:

Chemical engineering education in the U.S.S.R.

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Most of the information in Part I of this article, "Chemical Engineering in the USSR," applied to all of the engineering curricula as well as to chemical engineering. In the following sections an effort will be made to compare a specific chemical engineering curriculum in the USSR with a typical accredited chemical engineering curriculum in our country. Again it should be emphasized that industry in the USSR is staffed almost entirely from graduates of the VTUZ's, and only to a very limited extent from graduates of universities. However, because of a peculiar stipulation that the VTUZ's may give diplomas only in the "applied sciences" and the universities may give diplomas only in the "basic sciences," the universities must supply industry with a certain number of chemists as opposed to chemical engineers.

According to N. M. Zhavoronkov, director of the Mendeleyev Chemical Engineering Institute of Moscow, the ratio of chemical engineers to chemists in industry runs about four or five to one. The figures which he supplied showed that on Sept. 15, 1956, the total number of day students studying chemical engineering in the USSR was 37,190; whereas, the total number of students studying chemistry with the intent of going into industry was 9,110. At the time of the visit of the Exchange Mission this ratio seemed to be about the same. Parenthetically is should be noted that the 9,110 is not the total number of students majoring in chemistry. The great majority of the students majoring in chemistry in the universities will have a career of teaching chemistry in the secondary schools.

Those graduates of the universities who major in chemistry and go into industry are generally employed in the various control laboratories, so that the techniques of analytical chemistry are heavily stressed. It should be noted when the curriculum is analyzed later that even the chemical engineers receive much more training in analytical chemistry in the USSR than is common in the United States.

In the first part of this account of chemical engineering in the USSR, (Table 1)* the Exchange Mission was able to identify 29 different curricula which could be classified as chemical engineering in the United States. The quota for each of these curricula is specified for each institution which teaches it by the central authority in Moscow—the Ministry of Education. Not only is the number of students specified, but the course content is laid out by the Ministry of Education, in minutest detail. The Uchebni Plan specifies the title of each of the courses, outlines in complete detail what subject matter shall be included in each course, the total number of hours of lectures, laboratories, recitations and seminars, and in which semester the course will be given. In fact, it was stated that the content of each particular course must not vary more than 10 percent from the prescribed outline without permission from the Ministry.

Obviously no plan can be perfect enough to specify exactly the number of jobs which will be available to the graduates in each of 30 different curricula in the chemical engineering field five years hence. The members of the mission, therefore, were exceedingly interested to determine how this problem was handled. A very fortunate, fortuitous circumstance occurred while the mission was visiting the Kuibyshev Polytechnic Institute. We met a young student who was obviously very anxious to speak English to the members of the mission and we were delighted to have the opportunity. We learned that the student had been born in Brooklyn shortly before World War II and that his parents and he had moved to Russia shortly after World War II, approximately 1947 or 1948. It was interesting to note that he still spoke English with a definite Brooklyn accent. In the course of the conversation with this young man we found that he was in the fourth year of the curriculum in "Oil and Gas Technology."

However, the pertinent point was that he told us that he had started four years earlier in a program called "Explosives Technology." In the course of his third year the course in "Explosives Technology" was discontinued at the Kuibyshev Polytechnic Institute, because according to this student, "the demand for persons in this specialty had decreased." Instead of being washed out of school, or being transferred to another school that had

**Table 1 appeared in Part I of this report, August, CEP.*

Education in U.S.S.R.

continued

a course in "Explosives Technology," he was given a choice of staying at the Kuibyshev Polytechnic Institute and transferring to either (a) the curriculum in "Oil and Gas Technology," (b) the "Organic Synthesis of Rubber Technology," or (c) the "Plastics Technology."

He chose the "Oil and Gas Technology" and we asked him how he got along.

He said that he got along very well except that he had to study rather hard for the first semester to make up some courses that were not covered in his original curriculum. When he was transferred he was told that it was his responsibility to acquire any knowledge that was necessary in the courses he had missed before his time of transfer.

The student's story was later verified by discussions at the Ministry of Education when the mission returned to Moscow from Kuibyshev. The Assistant Minister for Planning, Mr. Mozhko, confirmed that the specialty in "Explosives Technology" had been curtailed at several institutions including the Kuibyshev Polytechnic Institute. He further verified that the reason for curtailing the number of students in "Explosives Technology" curriculum was due to the fact that the ministry had reached a required number of specialists in that area and therefore the number needed for replacement was less than originally planned. The Assistant Minister further stated that the technique which had been described to us by this boy was the one that was commonly used when changes were made in the plan during the five-year period between the time the students enter and the time they graduate and are available for jobs.

The standard five-year curriculum in chemical engineering in the USSR will now be compared, as closely as possible, with a typical chemical engineering curriculum which has been accredited by the ECPD in the United States. The particular United States curriculum does not represent any one institution, but is a composite of four or five accepted curricula which this observer has visited.

Table 2 is a translation of the Uchebni Plan of study for the chemical engineering specialty "Technology of Rubber," while Table 3 shows, on a comparable basis, typical courses in a chemical engineering curriculum in the United States. It should be noted that the comparison is made on the basis of contact hours rather than credit hours. The contact hours in the USSR could be checked and counted but there was no way of equating these to comparable credit hours. So the credit hours in the United States were changed to the contact hour basis as shown in Table 3. The number of semester hours in this curriculum is 147.

By combining groups of courses into seven categories: (a) non-technical, (b) skill courses, (c) basic sciences, (d) engineering sciences, (e) analysis, design and engineering systems, (f) applied analysis, design in operation of a specific industry (which has no United States counterpart) and (g) diploma project (which likewise has no US counterpart), a quantitative comparison of the two curricula is shown in Table 4, and graphically in Figure 1. The most striking over-all difference is that the amount of outside preparation required in a four-year curriculum in the United States in hours is greater than the amount of outside preparation required in five years in the USSR.

Comparison by courses

It can be seen (Tables 2 and 3) that the course of study in the first two years has some striking similarities and some equally apparent differences. The dissimilarity in objectives of the non-technical courses is quite apparent. While in the United States there is stress on a broad education for the whole man, in the USSR the non-technical courses are aimed at two major objectives: (a) indoctrination into the system through the courses in "Foundation of Marxism and Leninism," and "Political Economy" which run through the first eight semesters, and (b) increasing skill in the use of a foreign language. The mission found that the foreign languages elected by the students ran about 50 percent English, 40 percent German, and 10 percent all other languages. The mathematics taught in the two countries in the first two years is entirely comparable in subject matter, starting with analytical geometry in the first year and ending with differential equations at the end of the second year.

The physics course in the USSR seemed to be taught at a somewhat more sophisticated level than was the usual case in the United States, but there was no major difference. In the chemistry courses, the general chemistry in the United States contains more descriptive matter than was the case in the USSR. Apparently in Russia they are able to count on the students' background in general chemistry from their training in the 10-year schools. Therefore, the

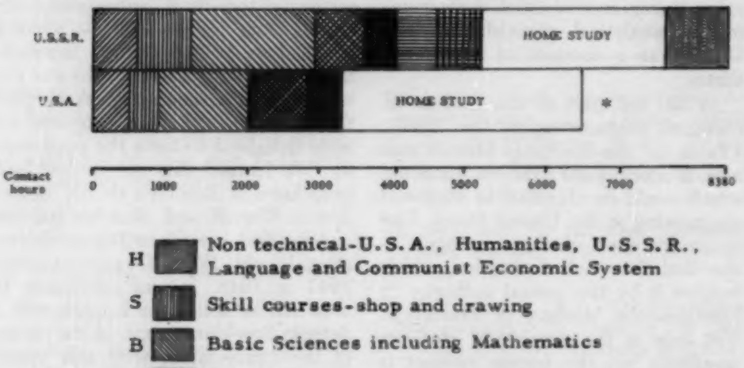

Figure 1. A quantitative comparison of the two curricula.

first-year chemistry is generally more mathematical than is the case in the USA. It is really an introductory course in physical chemistry. However, in this first-year course there is a difference in the way it is taught, depending on which specialty the student is taking. For example, in the "Technology of Rubber," which is under discussion here, there is stress on the rubber industry. Every effort is made to segregate the students in the first year into sections taking the same specialty. Mixing with students taking different courses is discouraged as much as possible. This is just the reverse of the USA philosophy and practice.

The emphasis on skills in the Russian curriculum as compared to that in the American curriculum is brought out forcibly in the different amount of analytical chemistry required of students in the United States and those in Russia. In the United States the most common pattern is a one-semester course in quantitative analysis, consisting of two lecture or recitation hours per week and two three-hour laboratory sessions per week for a total of 96 contact hours and presumably another 96 hours of outside preparation. In the USSR there is required a total of 290 contact hours, divided 30 hours of lecture and 260 hours of laboratory with only about 30 hours of required outside preparation. The students, on completion of the course in analytical chemistry in Russia, are expected to be able to perform the usual gravimetric and volumetric analyses required in control laboratories.

The general courses in organic chemistry and physical chemistry required in the two countries seem to be about the same in both intensity and order of magnitude. However the Russian students get an additional semester of a specialty in physical chemistry depending on the curriculum. For example, in this "Technology of Rubber" specialty they get a course in colloid chemistry. (Course 16 in Table 2.)

In the third and fourth years students in the USA get a series of courses covering the general principles in the Engineering Sciences and the accepted procedures in Analysis, Design and Engineering Systems (Table 3). The comparable students in the USSR get about the same amount of Engineering Sciences and general principles of Analysis, Design and Engineering Systems as those in the United States. But in addition they get a rather concentrated dose of special courses which shall be called "Applied Analysis, Design and

Table 2. Uchebni plan of study—USSR chemical engineering specialty: Technology of Rubber.

Course Name	Contact Hours: Total	Lecture	Laboratory	Recitation & Calculation	Seminar	Project Work	Semester in which given	Course group number
1. Foundation of Marx-Leninism	250	160	..	..	90	..	1, 2, 3, 4	H
2. Political Economy	138	100	..	..	38	..	5, 6, 7, 8	H
3. Foreign Language	136	..	..	136	..	..	1, 2, 3, 4	H
4. Physical Education	136	..	136	..	..	..	1, 2, 3, 4	S
5. Mathematics	328	164	..	164	..	..	1, 2, 3	B
6. Physics	232	132	70	30	..	..	2, 3, 4	B
7. Descriptive Geometry & Drawing	208	36	..	172	..	..	1, 2	S
8. Metallurgy	84	36	12	36	..	..	5, 6	E
9. Statics & Dynamics	100	60	..	40	..	..	2, 3	E
10. Strength of Materials	100	50	20	30	..	..	3, 4	E
11. Shop Operations	136	92	20	..	..	24	4, 5. 6	S
12. Inorganic Chem.	222	100	122	..	..	..	1, 2	B
13. Analytical Chem.	290	30	260	..	..	..	3, 4	B
14. Organic Chemistry	272	100	172	..	..	..	3, 4, 5	B
15. Physical Chemistry	254	100	154	..	..	..	5, 6	B
16. Colloid Chemistry.	72	32	40	..	..	..	7	B
17. Thermodynamics .	148	86	34	16	..	12	4, 5	E
18. Electrical Engin.	132	68	40	24	..	..	5, 6	E
19. Gen'l. Chemical Eng. Principles.	132	102	30	..	..	..	6, 7	E
20. Processes & Devices of Chem. Technology ...	212	102	72	18	..	20	6, 7, 8	A
21. Automation & Control of Chem. Processes	72	36	36	..	..	..	7	A
22. Safety, Accident & Fire Prevention	30	20	10	..	..	..	8	S
23. Economics of Chem. Ind. ...	40	40	..	..	..	..	8	A
24. Organization and Planning of Jobs	60	36	..	12	..	12	9	S
25. Construction Foundations and Sanitation	36	36	..	..	..	..	9	S
26. Physics & Chem. of Rubber	178	66	112	..	..	..	7, 8	AA
27. Chemical Engin. of Rubber	208	60	124	..	..	24	7, 8, 9	AA
28. Equipment in Rubber Mfg. ..	58	58	..	..	..	..	7, 8	S
29. Special Rubber Technology ...	156	96	60	..	..	..	9	AA
30. Diploma Project..	576	..	..	..	..	576	10	D
Totals	4996	1998	1524	678	128	668		

Number of Examinations — 33

Work Periods:
4 weeks after Semester 6
8 weeks after Semester 8
8 weeks after Semester 9

Total Course: 4 years, 10 months (actual in school 156 weeks plus 20 weeks factory work plus examination time).

Code

H = Nontechnical Courses
S = Skill Courses
B = Basic Sciences
E = Engineering Sciences
A = Analysis, Design & Engineering Systems
AA = Applied Analysis, Design & Engineering Systems
D = Diploma Project

Education in U.S.S.R.

continued

Engineering Systems." These courses (No. 26, 27, and 29 in Table 2) cover specific subject matter in the rubber industry, including not only applications of the Engineering Sciences to specific subject matter, but also Applied Design in various phases of the rubber industry. In addition the Russian student is given specialized skill courses in his fourth and fifth years (No. 22, 24, 25, and 28) which have no counterpart in the United States. As a matter of fact, most of the subject matter in these courses the United States student is expected to receive during his first year on the job, or by outside reading. Some of that information is given to the United States student through meetings of various student organizations, such as the student chapters of A.I.Ch.E. In Russia specialists from industry are brought to the Institute to lecture to the students in such courses as "Safety, Accident and Fire Prevention" (No. 22), and "Organization and Planning of Undertakings" (No. 24). These lectures are analogous to those of the speakers who will be invited at various times to talk to the student organizations on the typical United States campus.

Summary of the two curricula by areas

Summarizing the two curricula (Table 4), the number of non-technical courses in the two countries is quite comparable, except that the objectives of the two are not the same. Included in the skill courses in the United States is ROTC. There is nothing comparable to this in Russia, since apparently the Russians depend on purely military schools for the training of all their officers and do not rely on the civilian institutions. Thus it appears that the USSR student devotes much more time to civilian type skill courses than his American counterpart.

The basic sciences, including mathematics, appear to be entirely comparable in the two countries, especially if a factor for outside preparation is included in the USA contact hour total.

In the United States, in such courses as unit operations laboratory, the students perform their experiments and take their data in the laboratory. They are then expected to work either individually or in groups to prepare a report using additional time outside of class.

The procedure is different in the USSR. The students perform the ex-

Table 3. Typical Curriculum—USA Chemical Engineering

Course Name	Content Hours: Total	Content Hours: Lectures & Recitations	Content Hours: Laboratory	Semester in Which Given	Course Group Number
1. English	96	96	...	1, 2	H
2. Economics	96	96	...	3, 4	H
3. History & Government	96	96	...	5, 7	H
4. Humanities Electives	144	144	...	7, 8	H
5. Drawing & Descriptive Geometry	128	32	96	1, 2	S
6. ROTC & Phys. Ed.	256	64	192	1, ,2, 3, 4	S
7. Mathematics	256	256	...	1, 2, 3, 4	B
8. Physics	288	144	144	2, 3, 4	B
9. Gen'l. Chemistry	192	96	96	1, 2	B
10. Analytical Chemistry	96	48	48	3	B
11. Organic Chemistry	192	96	96	5, 6	B
12. Physical Chemistry	192	96	96	4, 5	B
13. Static, Dynamics & Strength of Metals	96	96	...	3, 4 3, 5	E
14. Electrical Engineering	192	96	96	6, 7	E
15. Engineering Materials	48	48	...	8	E
16. Ch. E. Stoichiometry	48	48	...	4	E
17. Ch. E. Thermodynamics	96	96	...	6, 7	E
18. Principals of Chem. Engineering	288	96	192	5, 6*	E
19. Ch. E. Processes	96	96	...	7, 8	A
20. Ch. E. Design	160	64	96	7, 8	A
21. Ch. E. Technical Elective	96	96	...	7, 8	A
Net Totals	3152	2000	1152		

Total Course = 128* weeks in school in 3 years and 9 months including examination time. Semester credit hours equal 147.

*plus extra summer sessions between years 3 and 4 in some cases as accredited by A.I.Ch.E. and E.C.P.D.

H = Nontechnical courses
S = Skill courses
B = Basic Sciences
E = Engineering Sciences
A = Analysis, Design & Engineering Systems

Table 4. Comparison of USSR and USA Chemical Engineering Curricula by Types of Courses

	USA Contact Hours	%	USSR Contact Hours	%
1. Non-technical courses	432	13.7	524	10.5
2. Skill courses	384	12.2	664	13.3
3. Basic Science, including Mathematics	1216	38.5	1670	33.4
4. Engineering Sciences	768	24.4	696	13.9
5. Analysis, Design & Engineering Systems	352	11.2	324	6.5
6. Special Applied Technology	....	....	542	10.8
7. Diploma Project	....	....	576	11.5
Totals	3152	100.0	4996	99.9
Outside Preparation (estimated)*	3000		2500	
Grand Totals	6152		7496	
Elapsed Time	3 yrs. 9 mo.		4 yrs. 10 mo.	

*Basis for estimation in the USA: 1 credit hour equals 1 hour in class plus 2 hours of preparation or 3 laboratory hours. In the USSR one half-hour outside preparation for each contact hour.

periments in the laboratory and then (see Figure 1) they work together as a group in class time with the professor to prepare their reports.

In the field of Engineering Sciences, the United States chemical engineering student appears to get a somewhat broader and more general dose. In the area of *general* analysis and design the two appear to be comparable, but if the courses (Nos. 26, 27, and 28) labeled special *applied* design technology in the USSR are included, the Russians would be appreciably ahead.

The diploma project

The final course which the Russian student has, and for which there is no American counterpart, is a full semester of 18 weeks on his diploma project. The diploma project may be of two types. For the great majority of the students the project is an applied design problem in connection with the particular industry in which the student is to be employed after receiving his diploma. In many cases the student has the diploma project suggested to him while on the job in industry in the interval of two months between the ninth and tenth semesters.

In the minority of cases with the more talented students, the diploma project may be a start on a research project assisting his professor on one of his research programs. The caliber of an institution can be judged by the number of students in the tenth semester who do their diploma project on a research program as compared to a design program. For example, approximately 30 to 40 percent of the students at the Mendeleyev Institute of Chemical Engineering in Moscow were engaged in diploma projects that could be classified as the beginnings of research; whereas at the Kuibyshev Polytechnic Institute only one or two students in each specialty were so engaged.

One other point should be noted here. The special five-and-a-half-year curricula, which were alluded to in the first part of this article, are reserved for the 15 or 16 leading institutions in Russia. These are the experimental institutions making advances in the various curricula. These changes are tried on an experimental basis with the approval of the Ministry of Education. Those changes which are considered successful are then incorporated into the regular five-year curricula. The various physical chemistry specialties at the Mendeleyev Institute were the only five-and-a-half-year programs in chemical engineering that were observed by the Exchange Mission. More than half the students enrolled in these five-and-a-half-year curricula did their diploma project on the beginnings of a research program. This is further evidence of student selectivity by specialty.

It is expected that those students who do their diploma project on the beginning of research programs will be employed either at an academy of science in a full-time research career, or at a VTUZ on a combination teaching and research career. They may be required to go into industry for one or two years immediately after getting their diplomas, but they are tabbed for a career of research and teaching. They start graduate work as soon as possible, sometimes while still in industry.

The end products

As noted previously, when the Russian student receives his diploma after four years and 10 months total elapsed time, he is given approximately two months leave of absence. Thus he is ready to begin his sixth year after entering the VTUZ as a full-fledged member of industry. He is guaranteed by the Ministry of Education a job of not lower grade than foreman. The better students are spotted for careers in research, and after receiving an advanced degree will eventually be professors in either an academy of science, where research is a full-time job, or in a VTUZ where research is 50 percent of the job and teaching is the other 50 percent. During the five-year undergraduate period, the chemical engineering student has had approximately 20 weeks of industrial experience, plus many practical courses in the VTUZ's.

The American student, on the other hand, received his bachelor's degree at the end of three years and nine months. He has had approximately 65 percent as many contact hours of classwork as his Russian counterpart, but he has been expected to spend more time in outside preparation, which considerably lessens the apparent disparity. At the end of three years and nine months, when he receives his bachelor's degree, he has had little or no specialized training in any particular industry, nor any courses aimed towards a particular industry, unless he has worked in the summers. On the other hand, his general background is equal, or superior in some phases, to that of his Russian counterpart. The American bachelor's degree recipient then goes

Building of the headquarters of the Petroleum industry at Kuibyshev.

to work for industry and gets a concentrated dose in his first year in industry of many of the things which the Russian student has obtained piecemeal while at the VTUZ.

Therefore, it is the opinion of this reporter, and this opinion is shared by all the members of the Exchange Mission, that at the end of five years the Russian VTUZ diploma recipient, with intervals in industry, and the American bachelor's degree recipient who has had three years and nine months in a university and one year and three months in industry, are comparable both from a technical and experience standpoint. The major difference appears to be that the Russian student is motivated to work much harder while in school than the American student. The reason is that the rewards for achieving a diploma, and the penalties for failure to achieve the diploma, are much more significant in Russia than they are in the United States. Thus they are producing a larger number of comparably trained people.

Our danger in the United States must be faced from two points of view. First, we are losing too many of our students who are able to graduate and who drop out for lack of motivation or other reasons. Second, our better students are not working as hard as they might simply because they are not forced to work that hard. Thus we are losing much potential. While the Russian system of engineering education in general is not considered superior to that in the United States, there are some areas in which they appear to be doing better than we are. We should be willing to learn how to take advantage of these strong points of their's without losing those things which are our strength and make us superior. The only real danger is to underestimate the Russian system and to fall into the trap of complacency. #

....production of Heavy Water

The wraps are off! Here are the engineering details of the "Spevack"* process for the production of heavy water by dual temperature exchange using hydrogen sulfide. Known as the GS process, it is now in use at AEC's Savannah River plant.

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**U.S. Patent 2,895,803 (J. S. Spevack), was issued July 21, 1959, pertaining to process design of dual-temperature exchange.*

Both the Dana and Savannah River heavy water plants use the GS process only for the extraction of D_2O from natural water and its concentration to 15-20%. The GS process is in no sense limited to this percentage as a maximum. For reasons of operating convenience, dependability, and flexibility, simpler processes were chosen for final concentration. These processes, vacuum distillation to 90-95% and electrolysis to 99.8%, although less efficient in their use of energy, operate on such small volumes of concentrate that they contribute negligibly to cost.

Principle of the GS process

The GS process is based on the reaction:

$$H_2O + HDS = HDO + H_2S \quad (1)$$

This reaction takes place in the liquid phase between water and dissolved hydrogen sulfide, the equilibrium constant being:

$$K_e = \frac{[HDO]_l\,[H_2S]_l}{[H_2O]_l\,[HDS]_l} \quad (2)$$

where $[HDO]_l$ and $[H_2O]_l$ are the mol fractions of these components in the liquid phase and $[H_2S]_l$ and $[HDS]_l$ are mol fractions dissolved in the liquid phase.

This equilibrium constant varies considerably with temperature, Figure 3, and it is this variation that provides the basis for the separation achieved in the GS process.

That a separation is qualitatively possible may be seen by consideration of a system of two vessels through which H_2S gas is circulated in series, countercurrent to a stream of water. The arrangement is shown in Figure 4. In this simplified illustration gas is bubbled through one pool of liquid in each vessel. Secondary considerations of humidity and solubility are ignored, but it should be noted that hydrogen sulfide is soluble in water and is free to enter and leave the liquid phase so that HDS can transfer and reach equilibrium between gas and liquid phases. The system will approach a steady state with the pools of liquid in equilibrium with the gas stream at their respective temperatures. Equation (2) can be rewritten,

$$\frac{[HDO]_l}{[H_2O]_l} = K\,\frac{[HDS]_g}{[H_2S]_g} \quad (3)$$

At low concentrations $[H_2O]_l$ and $[H_2S]_g$ are nearly unity and vary insignificantly with change in the other two components, hence, approximately,

$$[HDO]_l = K\,[HDS]_g \quad (4)$$

As pointed out, K varies inversely with temperature, so its value in the cold vessel, K_c, is greater than in the hot, K_h. Because of this difference, the concentration of HDO in the liquid in the cold vessel in equilibrium with the circulating gas (which has the same concentration in both vessels) is higher than in the hot vessel. Stated algebraically,

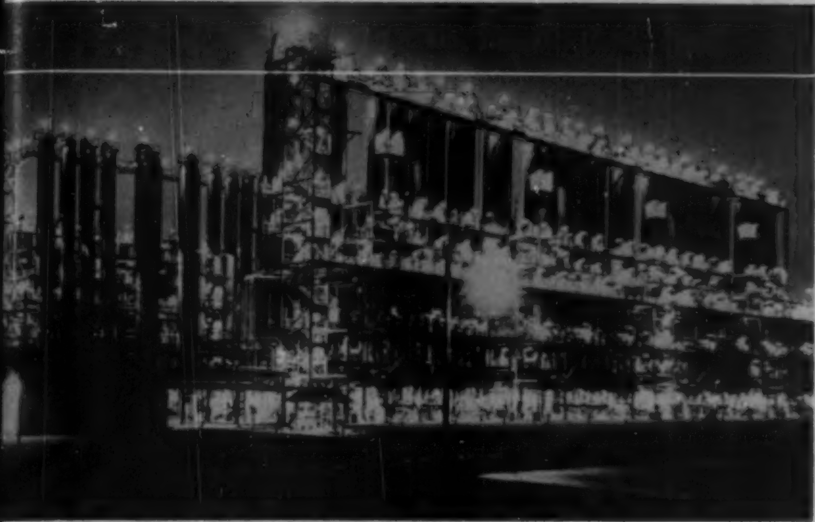
$$K_c > K_h \quad (5)$$

hence from Equation (4)

$$[HDO]_{l,c} > [HDO]_{l,h} \quad (6)$$

If no product is removed from the system by way of the product stream (Figure 4), the concentration in the

The information contained in this article was developed during the course of work under contract AT(07-2)-1 with the U. S. Atomic Energy Commission.



The Savannah River plant operating at night.

hot vessel must at steady state reach that of the feed, and the concentration in the cold vessel must be somewhat higher. Withdrawal of material at P will lower the concentration in both vessels somewhat; the hot vessel (*i.e.*, waste) will fall below feed concentration and the cold vessel (*i.e.*, product) will remain above. The system thus becomes productive; the feed will be split into two portions, an enriched product stream and a depleted waste stream.

Process design

The basic element of the GS process is a pair of gas-liquid contacting towers, one of which operates at 30-40°C. (the cold tower) and the other at 120-140°C. (the hot tower). Water passes downward through the cold tower and then through the hot tower, countercurrent to H_2S gas at a pressure of about 275 lb./sq. in. The gas is circulated by a centrifugal blower from the top of the cold tower to the base of the hot tower. The water is progressively enriched in D_2O as it flows through the cold tower, and progressively depleted as it flows through the hot tower. The water leaves the hot tower at a concentration lower than that at which it entered the system so that D_2O builds up in the system and can be withdrawn as an enriched fraction from the base of the cold tower (or the top of the hot tower).

The operating conditions chosen represent approximately the economic optimum for the system. They are defined mainly by the physical properties of hydrogen sulfide. The goal of process design, in principle, is to achieve the largest possible difference between the temperatures of cold and hot towers. It is also advantageous to operate at high pressures to attain high mass flow rates at allowable linear velocities in towers of reasonable diameter. The upper limit of pressure is fairly well defined as that at which hydrogen sulfide liquefies, or its solid hydrate forms at a given cold tower temperature. The triple point for the hydrogen sulfide-water system is at 29.5°C and 325 lb./sq. in. abs. With the upper limit of pressure set in this range, it is expedient to choose a pressure within the operating limit of the nearest standard series of valves and fittings. In the plants described, 300-pound standard fittings were used with the maximum pressure at about 300 lb./sq. in. ga. The optimum temperature for the hot tower is not so well defined, but above about 140-150°C the gains from increase in temperature are more than offset by the rapid increase in the concentration of water vapor in the gas.

The calculations of fractionation and recovery are similar to those for distillation and the more usual gas-absorption processes. Under the conditions chosen, the humidity of the gas and the solubility of gas in the liquid cannot be ignored. For these calculations, an overall distribution factor, β, is calculated. This factor expresses the overall relation between the concentration of deuterium in the gas stream, both as HDS and as HDO vapor, to that in the liquid stream, as HDO and dissolved HDS*.

---

*The overall separation factor, β, is calculated from the relation:

$$\beta = \frac{(1+H)\,(S+K_s)}{\alpha(1+S)\,(1+HK_s)}$$

where: H = mols of water vapor per mol of gas

S = mols of dissolved sulfide per mol of liquid water

K_s = equilibrium constant in terms of concentrations in the liquid phase, *i.e.*,

$$K_s = \frac{[HDO]_l\ [H_2S]_l}{[H_2O]_l\ [HDS]_l}$$

α = relative volatility of H_2O and HDO, which, it has been found, can be assumed to be equal also to that of H_2S and HDS.

By definition,

$$\beta = \frac{x\,(1-y)}{y\,(1-x)} \qquad (7)$$

where: x = atom fraction D in the liquid phase, and

y = atom fraction D in the gas phase, as defined above

At 30 and 130°C, at a pressure of 275 lb./ sq. in. ga., β is 2.29 and 1.63, respectively. The equilibrium diagram for the full concentration range is shown in Figure 5. At low concentrations, up to 1 to 2% D, the terms $(1-x)$ and $(1-y)$ may be ignored, the equilibrium lines being

continued

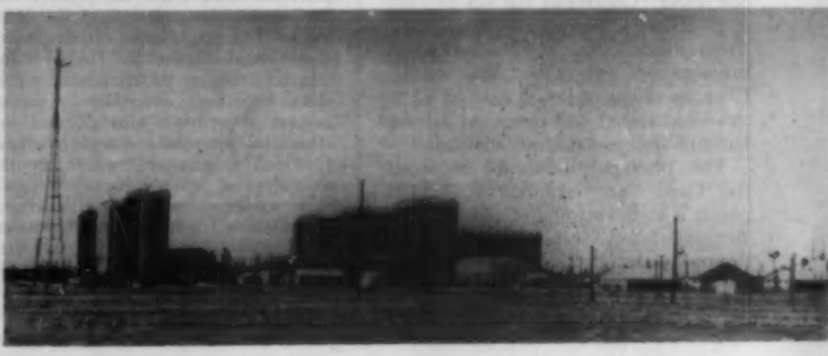


Figure 1. General view of the Dana plant.

continued

considered straight, with slopes equal to $1/\beta$.

The change in concentration through a GS tower can be determined by the usual stepwise progression defined by an equilibrium line and an operating line for the column (similar to the McCabe-Thiele method for distillation). The operating line has a slope equal to the ratio of liquid to gas flows and an intercept dependent upon the rate of production of D_2O. A typical diagram for a first-stage tower pair is represented by Figure 6. The difference between the slopes of the hot and cold tower operating lines is due primarily to the water vapor in the hot gas. The production rate is proportional to the distance between x_{oc} and x_{oh}, the intercepts of the cold and hot operating lines, respectively.

Figure 6 shows that there is very little latitude for variation of slope of the operating lines if these lines are both to diverge from their corresponding equilibrium lines. The optimum situation is that in which the pair of operating lines is "mathematically" centered between the equilibrium lines, that is, that the ratio of the slope of the equilibrium line to that of the operating line for the hot tower is equal to the reciprocal of that ratio for the cold tower. The effect of deviation from optimum is shown in Figure 7, a plot of relative production rate (assuming a constant product composition) against the liquid-to-gas ratio in the cold tower. It is important to note that unlike most processes that involve distillation or the countercurrent contacting of gas and liquid, there is in the GS process no direction of deviation from the optimum flow ratio that is safe and conservative.

The analysis of GS tower operating diagrams reveals a very sensitive and useful criterion of control. If the flow ratios are optimum, the concentration at the middle tray of the cold tower will equal that at the middle of the hot tower. Control of the GS process is based on sampling and analysis at these points, obviating precise measurement of absolute flow rates. Changes of gas or liquid flow of 0.5% can be detected and corrected on the basis of the mid-column analyses.

The principal difference between the Dana and Savannah River GS plants is in the staging of the cascade. Because heavy water is present in natural water to the extent of only one part in about 7000, very large flows must be handled in the feed stage of a heavy water plant, but these flows may be smaller in later stages as the concentration is increased. This reduction in flow permits a reduction in tower area, but at the expense of some increase in the number of total mass transfer units or theoretical plates required. As an example, in a GS unit at the Dana Plant, there are five stages, and the cold water passes over a total of 350 bubble-cap trays in series to reach 15-20% concentration. There is a similar number of trays in the hot towers.

The first stage is actually four pairs of hot and cold towers in parallel, having a total cross-sectional area in the first-stage cold towers of about 400 sq. ft. The second stage has an area of 100 sq. ft., and the fifth stage, 5 sq. ft. A Savannah River GS unit has only two stages with a total of 220 trays, hot or cold, in series. For the same first-stage area, 400 sq. ft., the equivalent second-stage area at Savannah River is 130 sq. ft. In principle, the tray area through the cascade could be reduced continuously as the concentration increases. This would result in a minimum total column volume, but the number of trays would be a maximum and

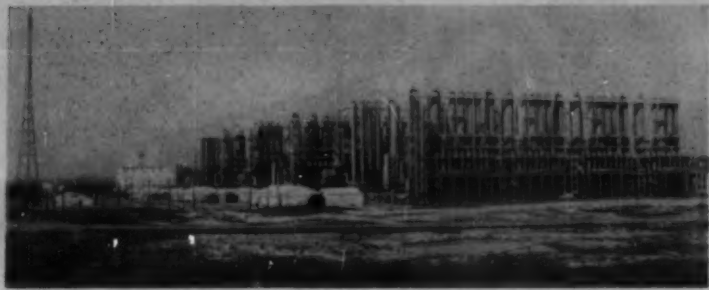


Figure 2. General view of the Savannah River plant.

History of Heavy water processing

Deuterium, heavy hydrogen, was first identified by H. C. Urey and his co-workers in 1931. Both deuterium and its oxide, heavy water, immediately became of great interest in chemical and biochemical research. About ten years later, at the inception of the wartime atomic energy project, it was recognized that heavy water would be an excellent moderator for a nuclear reactor to produce plutonium. Because of the uncertainty as to the procurability of heavy water, and after the graphite-moderated pile operated successfully at Chicago in 1942, graphite was chosen as the moderator for the reactors at Hanford. Considerable research was done, however, on heavy water processes, and some thirty tons was produced under contracts of the Manhattan District, Corps of Engineers. The methods used in the United States for the wartime production of heavy water have been described by several authors who have also pointed out other and potentially cheaper methods *(1-5)*. The general method for the separation of isotopes by dual-temperature exchange, which was developed at Columbia University under contracts of the OSRD and the Manhattan District, is described in a patent *(6)* issued April 2, 1957 (J. S. Spevack, assignor to the U. S. Government).

More recently, especially at the second Geneva Conference, there have been several papers reporting the efforts of other countries in this field *(7-18)*. Those by Weiss *(7)* and Roth *(9)* are notable in that they present significant analyses of the hydrogen sulfide exchange process and indicate Ch.E. considerations similar to those described here.

AEC program

In 1950, new reactors to produce plutonium and other special nuclear materials were planned as a part of a large expansion of the program and facilities of the Atomic Energy Commission. It was decided that these reactors, to be built at the new Savannah River plant, should be moderated with heavy water, and it was necessary to proceed rapidly with the design and construction of large new facilities for the production of the heavy water. The processes used in heavy water plants of the Atomic Energy Commission were declassified in 1956. Until recently, however, certain aspects have been subject to court restraints that have prevented publication.

Choice of process

No research and development work had been done on heavy water processes since the design of the Manhattan

the staging would be complex. In Figure 8, the Savannah River and Dana cascades are compared graphically with an approximation of such an "ideal" cascade. In practice, the continuous "taper" of the ideal cascade cannot be achieved nor will the limits of practicable construction permit full advantage to be taken of the reduction of area with increase in concentration. In the design of the GS plants relatively simple cascades with few stages were chosen at the expense of some increase in tower sizes in the higher stages.

The Dana plant has six 5-stage GS units and the Savannah River plant 24 two-stage units. The common denominator of the two plants is the first-stage column pair, a cold tower 11 ft. in diam. and a hot tower 12 ft. in diam. There are four of these pairs in each Dana unit and one in each Savannah River unit.

Figure 9 is a schematic flow diagram for a Dana unit and Figure 10 is a similar diagram for a Savannah River unit. For simplicity, these diagrams do not include the heat recovery systems. Table 1 is a summary of the comparative numbers and sizes of towers in the two plants.

The complete flow pattern through a GS unit, including the heat recovery circuits, can best be explained by reference to the simpler Savannah River unit. The interstage connections and the heat recovery circuits differ somewhat between Dana and Savannah River, but in principle represent conventional chemical engineering approaches to the problems of heating and cooling large flows of water-saturated gas. Figure 11 is a more complete flow diagram for such a unit, including its principal auxiliaries. Feed water enters the unit at the top of the first-stage cold tower (CT-1), passes down through that tower, is heated in the first-stage liquid heater (LH-1), and passes down through the first-stage hot tower (HT-1) to the eleventh tray, from which it is drawn off through the waste stripper (S-1) and discarded. Gas is circulated from the top of the cold tower by a centrifugal blower (GB-1) through the bottom ten trays of HT-1 where it is heated, through the upper 60 trays of HT-1, through two cooler-condensers (PC-1 and SC-1) and thence through CT-1.

The second stage in essence provides a by-pass for roughly one third of the first-stage streams around the LH-1, PC-1 and SC-1.

All of the heat input to the system is by direct steam injection to S-1, where the steam serves also to strip hydrogen sulfide from the waste water. Stripping is enhanced and steam saved by preheating the stripper feed in heat exchanger SX-1. The waste water provides heat for

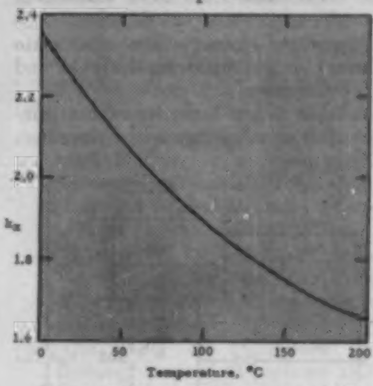


Figure 3. Effect of temp. on equilib. const. for exchange of Deuterium between dissolved H_2S and water.

District facilities. The possibilities that existed in 1943-45 were reassessed in the light of the somewhat different time schedules and availabilities of materials. Three processes were given most serious consideration: vacuum distillation of water, the distillation of liquid hydrogen, and exchange of water with hydrogen sulfide gas in a dual-temperature cycle.

Each of the three processes mentioned had reasonable promise, but had its own real or potential shortcoming. Water distillation was known to be workable but at great consumption of thermal energy. Hydrogen distillation was attractive because of the large difference in volatility between hydrogen and deuterium, but the handling of liquid hydrogen in large plants had not been demonstrated, and the quantities of hydrogen required as raw material were not readily available. Hydrogen sulfide exchange appeared feasible, based on some equilibrium data and very limited small semiworks demonstration, but difficulty of process control, the toxicity of the gas and its corrosiveness were so severe that choice of this process had been discouraged.

In 1949 the AEC asked the Girdler Corporation to design and operate a pilot plant and to design a production unit based on the hydrogen sulfide (GS) process. Hydrocarbon Research, Inc. was asked to make design and feasibility studies of hydrogen distillation. When du Pont entered the program in 1950, as prime contractor for the project, consideration of various modifications of water distillation was brought in. An evaluation of the three processes showed clear advantages for the GS process provided that its three potential obstacles, namely the problems of control, toxicity, and corrosion, could be overcome. At this juncture du Pont joined forces with Girdler to assist in design, and in the development activities, including operation of the pilot plant and an extensive program of corrosion research.

Late in 1950 the pilot plant built by Girdler at Wabash River Ordnance Works near Terre Haute, Indiana, was operated sufficiently to demonstrate that the process data upon which plant design was being based were valid and that tray efficiencies would be reasonably good. The demonstration was done in one pair of towers, hot and cold, the first stage of a four-stage pilot plant. Subsequent operation of the pilot plant served mainly to emphasize the problems of corrosion and fouling of equipment by wet hydrogen sulfide, and to point the direction for research and development effort. Operation in sub-zero weather revealed the problem of preventing plugging by the hydrate of hydrogen sulfide, which solidifies at about 30°C at the chosen operating pressure. The pilot plant served well to demonstrate the obstacles to be overcome in operating the larger units to come, although those obstacles prevented its operation as an integrated four-stage unit.

Construction of plants

Engineering design and construction of a heavy water production plant based on six large GS units embodying a five-stage, series-parallel cascade was done by the Girdler Corporation for du Pont in 1951-52. The plant was built on part of the Wabash River site and was named the Dana plant. The existing power and water facilities and a part of the wartime D_2O unit were incorporated into the AEC facility.

The schedule for construction of the nuclear reactors at Savannah River plant required a rate of accumulation of heavy water greater than could be expected from the Dana plant, so that in 1951 design and construction was begun on a similar facility for Savannah River. The designers of this plant had the benefit of some experience with the Dana pilot plant, and of considerable corrosion research. This new information was used as the basis for certain changes of flowsheet and materials of construction. These differences between the plants are discussed in the article, but in capacity and operating principle the plants are similar. The similarity is evident in the photographs of the two plants, Figures 1 and 2. The Lummus Company did the engineering design, and du Pont the construction, of the Savannah River heavy water plant.

LH-1 and LH-2. Water is heated in PC-1 and PC-2 and circulated over the heater-humidifier trays in HT-1. The gas coolers, SC-1 and SC-2, are cooled with process cooling water. The gain in sensible heat of this water and the sensible heat of the waste water from LH-1 and LH-2 represent the major heat losses from the system.

Product is withdrawn from the unit as condensate from PC-2 and SC-2, condensate being used since it is somewhat cleaner than the main liquid stream between the cold and hot towers.

Table 2 is a summary of the principal flow rates through a Savannah River unit.

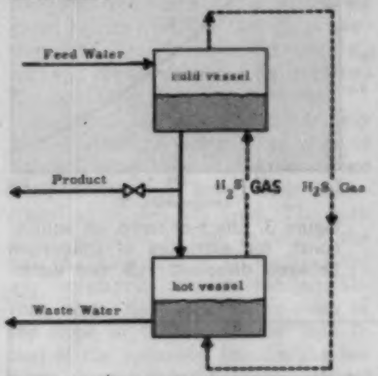


Figure 4. The principle of dual-temperature separation. (Schematic).

The heat recovery system and interstage connections are similar in the Dana units except for the complication of the four first-stage cold towers and four first-stage hot towers that are operated in parallel. Process control is more complicated at Dana since the gas and liquid streams between cold and hot towers of the first stage are combined to pass through the heat exchangers and must be split again among the individual towers.

Realization of the critical control problem and concern over the ability to solve it adequately in the Dana first stage led to the choice of the simplified flowsheet for Savannah River. Good control has proved quite feasible in both plants, however, but the Savannah River arrangement has shown advantages in ease of operation and maintenance. Particularly, periodic overhaul of the Savannah River units can be handled with smaller crews and less loss of production than at Dana.

Corrosion—materials of construction

The success of the GS process has been very largely due to research and development that defined the effects of H_2S on practicable materials of construction. Concurrently with the design and construction of the two plants, a major program of corrosion research was carried out. The results of this research were applied as they were obtained.

The important aspects of the effects of hydrogen sulfide on steels are summarized below:

(1) Carbon steel is corroded by H_2S in water, but the iron sulfide that is formed acts as a protective coating, so the corrosion, although very rapid at first, drops to a rate so low as to be negligible after about 1000 hr. of exposure. If, however, erosion prevents the formation of the sulfide coating, the corrosion

Table 1. Comparison of the number and sizes of principal towers in the Dana and Savannah River GS plants.

	DANA			SAVANNAH RIVER		
Stage	Number	Diameter (ft.)	Trays	Number	Diameter (ft.)	Trays
First						
Cold	24	11	70	24	11	70
Hot	24	12	60*	24	12	60*
Second						
Cold	6	11	70	48	6.5	85**
Hot	6	12	70	48	6.5	70
Third						
Cold	6	6	70	..	..	..
Hot	6	6.5	70	..	..	..
Fourth						
Cold	6	3.5	70	..	..	..
Hot	6	4	70	..	..	..
Fifth						
Cold	6	2.5	70	..	..	..
Hot	6	2.5	70	..	..	..

* Ten trays in each first-stage hot tower are used in the heat recovery system.

** The tray spacing in the SRP second-stage cold towers was reduced with corresponding relative increase in tower cross section. This modification was made to compensate for lower tray efficiency in the cold towers.

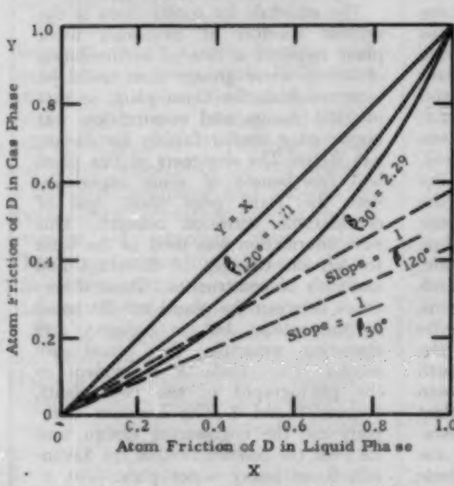


Figure 5. Typical gas-liquid equilibrium diagram.

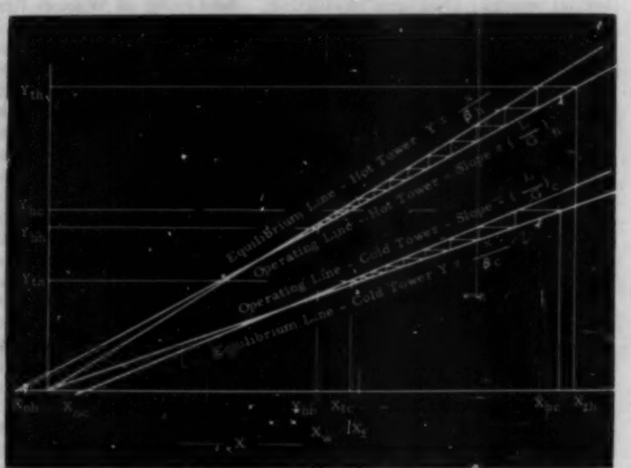


Figure 6. Operating diagram—typical pair of first stage towers.

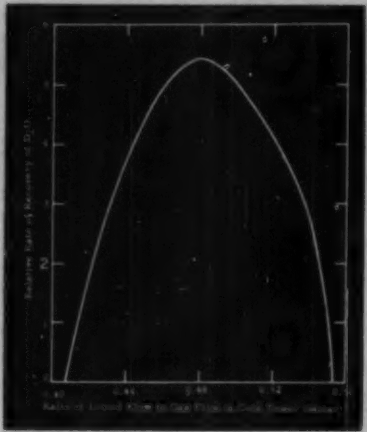


Figure 7. Effect of variation in flow ratio on a GS unit productivity.

rate continues high. Hence for the GS process, carbon steel may be used only for equipment not subject to highly turbulent water flow or to spray impingement. In practice, carbon steel is satisfactory for tower shells, heat exchanger shells (if nozzle entrances are protected), tanks, and most process piping.

(2) A portion of the hydrogen that is formed by the reaction of H_2S with steel diffuses into and through the metal. This diffusion gives rise to the two most troublesome effects of corrosion: stress corrosion cracking, and blistering. The hydrogen, apparently in the atomic state, diffuses readily through the crystal lattice of steel and combines to form molecular hydrogen only at surfaces of, or discontinuities in, metal. The presence of atomic hydrogen from the corrosion reaction seriously reduces the strength of hard, high strength steels or of steels having high residual stresses from cold working or welding. The effect is most pronounced and important with the high strength steels used for flange bolts and with hardened steels in springs and roller bearings.

Blistering is important with steels used for the fabrication of process pressure vessels. Any discontinuities such as voids, laminations, or nonmetallic inclusions can serve as loci for the combination and collection, as molecular hydrogen, of any atomic hydrogen that has diffused into the steel. The hydrogen so formed can apparently generate virtually any pressure necessary to create space for itself. If there are sizeable voids or laminations present in the steel plate, these will be enlarged by the hydrogen into blisters.

(3) No corrosion inhibitors are known that are practical for use under conditions of the GS process.

Table 2. Principal flow rates and operating conditions, Savannah River GS unit.

	First Stage	Second Stage
Flow of cold gas (p.p.h.)	620,000	170,000
Liquid flow (feed) (g.p.m.)	315	—
Pressure (top of CT) (p.s.i.g.)	280	—
Temperature: (°C)		
Cold tower ..	33	—
Hot tower ...	133	—
Concentration of D_2O at base of CT (mol %) .	0.085	15

Corrosion and its effects have been kept under control by the following measures:

(1) Where possible, low velocities are maintained in piping and vessels.

(2) Liquid entrainment is avoided in gas lines.

(3) Where high velocities are unavoidable, as in control valves and through bubble-cap trays and heat-exchanger tubes, austenitic (Cr-Ni) stainless steel is used. AISI Type 304 is acceptable, although Type 316 is most resistant.

Type 410 stainless steel (12-14% Cr) is usable only on the basis of a service life of about five years.

(4) In bolts, hardness is limited to Rc 27 and stresses (by measurement) to 40,000 lb./sq. in.

(5) Steel plate to be used for process vessels is carefully selected by ultrasonic inspection to insure freedom from fissures and voids.

(6) Instrument bellows, Bourdon tubes, and springs are isolated from H_2S.

(7) Liberal use is made of minimum-thickness holes at locations where erosion is to be anticipated. These holes, drilled about halfway through the pipe wall from the outside, give warning of serious penetration.

(8) The units are subjected to thorough annual inspections and hydrostatic tests.

The ferrous metals, carbon and stainless steels, are used for all important process applications except the impellers of the centrifugal blowers used to circulate gas. These are large in diameter and operate at high speed, and for these reasons are made

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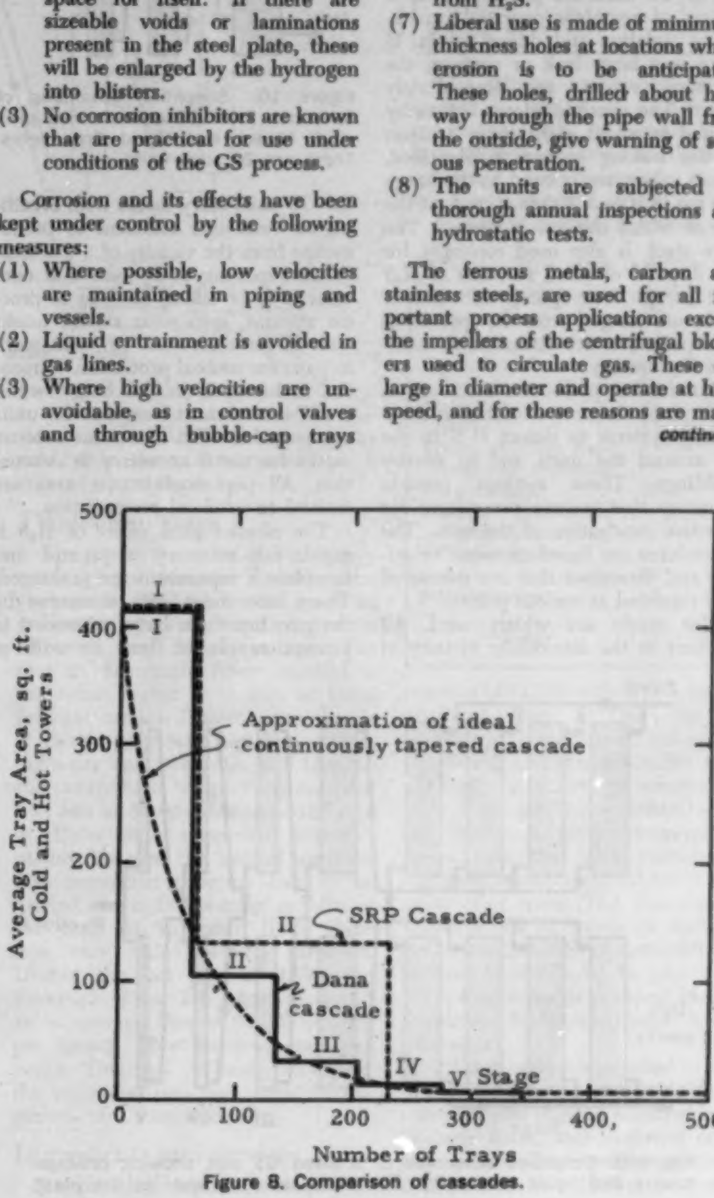

Figure 8. Comparison of cascades.

continued
of an aluminum alloy. The corrosion resistance of aluminum in this service is adequate so long as the gas is reasonably free from entrained water.

Control of hazards

The program for control of corrosion has reduced greatly the risk of release of H_2S gas. This gas is, nevertheless, highly toxic and there is more than 800 tons of it in each of the GS plants. A comprehensive safety program, beginning with the design of the GS units, is carried out to protect operating and neighboring personnel from both small and possible large releases of gas.

The GS units are provided with a system of remotely operated, quick-acting isolation and dump valves. If there is a large leak or rupture, the isolation valves are immediately closed. The possible release is thereby limited to about eight tons. As soon as the leaking section is identified, dump valves are opened to discharge the gas in it to a 400-foot stack at the top of which the gas is burned. The flare stack is also used routinely for the disposal of small amounts of H_2S that escape from pump and blower seals, are purged from equipment to be repaired, or are discarded to maintain H_2S quality.

For further protection there are in each plant elaborate continuous monitoring systems to detect H_2S in the air around the units and in nearby buildings. These systems provide warnings that initiate procedures for selective evacuation of the area. The procedures are based on wind velocities and directions that are measured and recorded at various points.

Gas masks are widely used. All workers in the immediate vicinity of the GS units carry masks with breathing-air reservoirs sufficient to permit escape from the vicinity of a gas leak. While repairing equipment that contains H_2S, or taking samples of process streams, men wear similar masks with larger reservoirs. All men work in pairs for mutual protection. Personnel in locations in the heavy water areas more distant from the GS units are provided with absorbent canister masks for use if necessary in evacuation. All personnel in the area are trained in artificial resuscitation.

The physiological effect of H_2S is rapid, but recovery is prompt and complete if exposure is not prolonged. There have been men overcome by the gas, but these have responded to prompt supply of fresh air with or without artificial respiration. The safety record has been good because of rigorous adherence to the safety program.

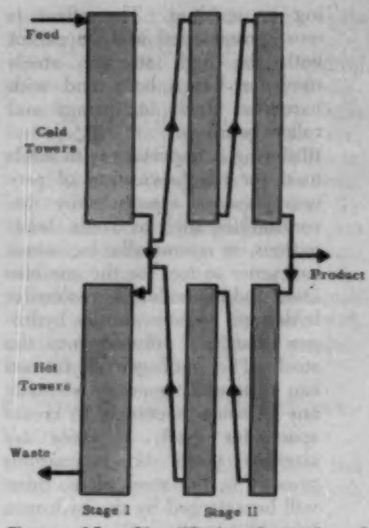

Figure 10. Simplified schematic of Savannah River GS unit showing principal towers and liquid flow paths. There are 24 such units.

Plant performance

The GS units at both the Dana and Savannah River plants have proved to be readily operable and extremely dependable. The units at Savannah River are in productive operation an average of 98% of the time. Most of the outage of 2% is the time for the annual overhaul and inspection, which requires about seven days. A Savannah River unit is vulnerable to complete shutdown as the result of failure of any of about six pumps or blowers that are part of it. The unit is, however, easily shut down and restarted and the failures are infrequent, so that spare pumps and blowers could not be justified. It is not unusual for a unit to run for a year without being shut down by a mechanical failure.

The Dana units on the other hand are provided with nearly complete sets of installed spare pumps and blowers so that complete shutdowns of a unit are even less frequent. The annual overhaul and inspection of the larger Dana unit requires about seventeen days, however.

The criterion of good process control in a GS unit is that the ratio of concentrations at the midpoints of corresponding cold and hot towers be so nearly unity that a change in flow rate of less than about 0.5% is indicated. The units can be kept in this state of control about 90% of the time.

As might be inferred from the stated percentage of operating time, corrosion has been kept under reasonable control. Much, however, has been learned about this problem in operation of the plants. In the early operation of Dana, carbon steel heat exchanger tubes and control valve bodies proved to be entirely unsuitable. Type 410 stainless steel trays and bubble caps have corroded to the extent that they require replacement after about four to five years. The general attack on carbon steel piping and vessel walls has not been appreciable. There have been a fairly large number of instances of the failure of bolts owing to stress corrosion cracking, and as the result of these failures, the specified hardness for these bolts has been reduced to a maximum of Rc 27, and the permissible stress to 40,000 lb./sq. in. Under these conditions, no failures occur. There have been no serious instances of blistering.

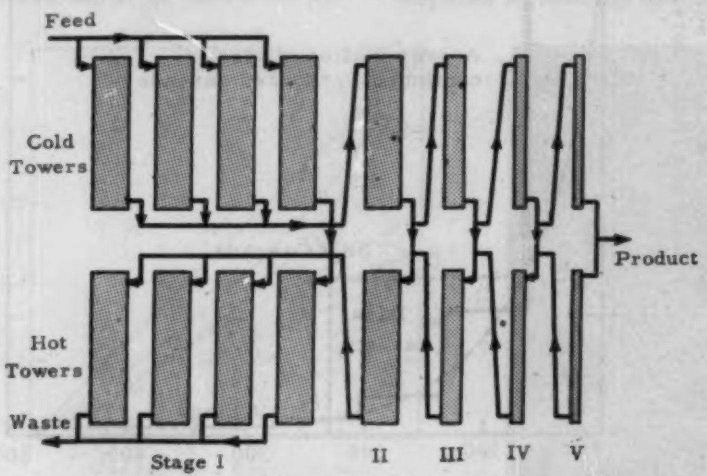

Figure 9. Simplified schematic of a Dana GS unit showing principal towers and liquid flow paths. There are six such units in the plant.

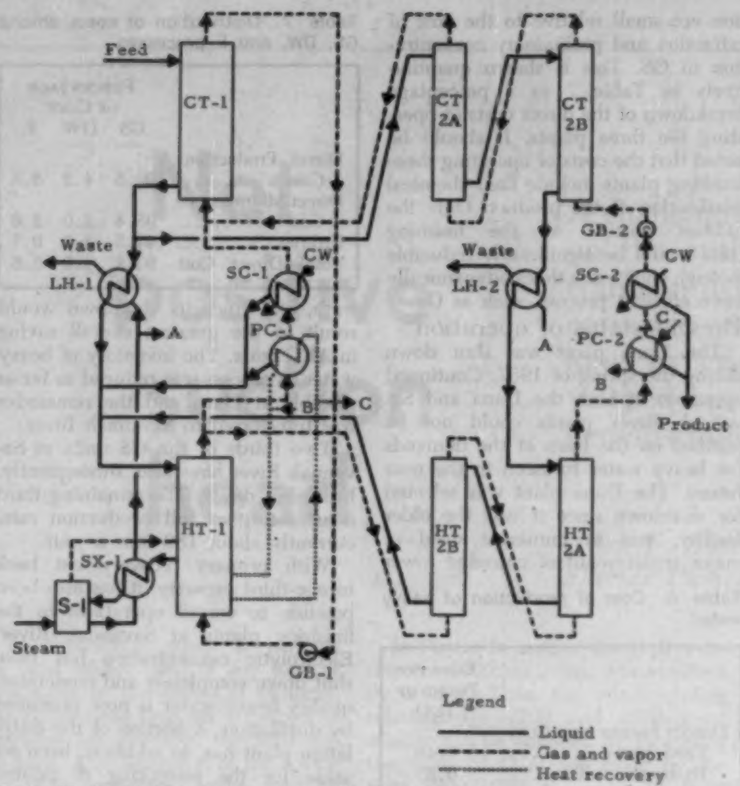

Figure 11. Flow diagram of a Savannah River GS unit.

There has been fairly rapid erosion of piping in certain isolated locations, generally where such erosion might be expected, and where minimum thickness holes were present to reveal its progress. These locations were at points of high velocity and turbulence, such as at junctions, bends, or changes in size of pipe. There are, however, unexplained differences between apparently identical configurations that operate under the same conditions in different units. Erosion does not always take place in situations where it might be expected. It is thought that these differences in behavior may be the result of unknown differences in residual stresses in the piping or in vibrational stresses, but this has not been proved.

The corrosion of large areas of Type 410 stainless steel (bubble caps and trays) presented an indirect problem at Dana. The solubility of the iron sulfide formed in the corrosion reaction varies inversely with temperature so that large quantities of it were precipitated in the waste strippers and their heat exchangers. This problem was solved by adding NaHS to the feed water, thereby increasing the sulfide ion concentration and reducing the solubility of iron sulfide. Most of the iron sulfide is thus precipitated where it is formed and the fouling of the stripping system is kept to an acceptable minimum. The sulfide from the NaHS was recovered by acidifying the waste water as it entered the stripper.

Production rates

The production rates of both heavy water plants increased steadily after start-up in 1952-53 as the result of continued effort to improve process efficiency and reduce outage. The rate at Savannah River reached a somewhat higher level than at Dana because certain differences in details of design permitted higher operating pressures and flow rates and because the outage time for periodic overhaul was less at Savannah River. The rate at Dana was somewhat seasonal, mainly because the annual overhaul and inspection program had to be carried out in the warmer months of the year. At Savannah River there was very little seasonal variation. During the last half of 1956, the Savannah River GS plant produced at an average rate of 83,000 pounds per month (five hundred tons per year). This was probably very near the maximum rate that might be expected on a sustained basis.

Ingredients and services

The principal requirements for producing D_2O by the GS process, exclusive of manpower, are the natural water used as feed, makeup hydrogen sulfide, energy, and cooling water. The quantities required, per pound of heavy water produced, are given in Table 3.

Table 3. Unit quantities of ingredients and services.

	Quantity Per Pound of D_2O
Treated feed water	3,500 gal.
Hydrogen sulfide	0.94 lb.
Electrical energy	310 kw.hr.
Process steam (equivalent 900 p.s.i.)	5,600 lb.
Cooling water	12,000 gal.

The process feed water must be treated to free it of dissolved and suspended solids. At Savannah River it is filtered, acidified to decompose carbonate, and deaerated; at Dana it must be softened by ion exchange.

Hydrogen sulfide is produced by reaction of NaHS with H_2SO_4 in small auxiliary plants. At Dana the small makeup is taken care of, however, by the direct addition of NaHS to the GS feed water already mentioned.

Table 4. Dana plant operating force.

Operation of	Supervisory	Non-Supervisory
Process Facilities	50	180
Maintenance	48	357
Utilities	14	60
Technical (Plant control and technical assistance)	25	38
Services (Medical, Patrol, Accounting, Transportation, etc.)	25	114
Administration	8	1
Total	170	750

At Savannah River, steam for the GS process is produced in a large powerhouse that also provides the electrical energy required for this and some other users. The steam is generated at 900 lb./sq. in. ga. and process steam for GS is extracted from turbines at 385 lb./sq. in. ga.

Cooling water is pumped from the Savannah River and used without treatment.

At Dana, steam is supplied at about 375 lb./sq. in. ga., cooling water is pumped from Ranney wells fed by the Wabash River, and electrical energy is purchased from public utilities. It is of interest to note that the portion

of the steam plant at Dana that supplies the GS process is the same that was required for the wartime water distillation process. The ratio of production capacities is about twenty, a measure of the economic superiority of the GS process.

Operating force

The Dana plant provided the best measure of the personnel requirement for the heavy water plants since it was operated as a separate facility, while the Savannah River units are part of a much larger plant having central administrative and service departments. The total operating force at Dana was 926 of which 170 were supervisory. The distribution of these numbers is given in Table 4.

Investment and operating cost

For the analysis of investment and operating costs, the Savannah River heavy water plant is best. This entire plant with its service facilities was built at one time so that the investment is an easily determinable figure. Also, although some electrical energy is exported from the heavy water area, the overall utility investment is much more nearly in correct proportion to process investment than at Dana where no electrical generation is provided.

Table 5. Savannah River heavy water plant, Investment (1951-52 Costs).

Process Facilities	Millions of Dollars
H_2S exchange (GS units)	113
Water distillation (DW)	2.5
Electrolysis (E)	1.5
Power Plant (Steam and electricity)	31
Water System (Process feed and cooling)	8
General Facilities (Offices, cafeteria, shops, roads, etc.)	7
Total	163

Production cost

The cost of producing heavy water is summarized in Table 6. These costs are based on the operation of the Savannah River heavy water plant during the last half of 1956. During that period the production rate was at the level that has been discussed and operation in general was normal and representative. The costs do not include any capital charges such as amortization or depreciation.

It was pointed out earlier that the costs of operating the distillation and electrolysis plants for final concentration are small relative to the cost of extraction and preliminary concentration in GS. This is shown quantitatively in Table 7 as a percentage breakdown of the direct costs of operating the three plants. It should be noted that the costs of operating these finishing plants include final chemical purification of the product. Only the utilities portion of the finishing costs would be significantly reducible through choice of a thermodynamically more efficient process, such as GS.

Present status of operation

The Dana plant was shut down during the spring of 1957. Continued operation of both the Dana and Savannah River plants could not be justified on the basis of the demands for heavy water foreseen in the near future. The Dana plant was selected for shutdown since it was the older facility, was in imminent need of major replacement of corroded tower trays, and since its shutdown would result in the greatest overall saving in AEC costs. The inventory of heavy water in process was reduced as far as possible at Dana and the remainder was transferred to Savannah River.

Table 6. Cost of production of heavy water.

	Cost per Pound of D_2O
Direct Production Cost	
Feed water	\$ 0.40
Hydrogen sulfide	0.35
Total materials	0.75
Salaries	0.37
Operating Labor	0.93
Miscellaneous supplies and expenses	0.15
Total direct production cost	2.20
Direct Maintenance Cost	
Labor	1.32
Material	0.49
Total direct maintenance cost	1.81
Utilities	
Electrical energy	1.33
Steam	4.40
Cooling water	0.12
Miscellaneous	0.06
Total utilities cost	5.91
Total Direct Cost	9.92
Administrative and General Expense (overhead)*	3.49
Total Expenditures	\$13.41

* *The principal single items entering into this cost are:*

Analytical control	*\$0.36*
Technical assistance	*0.25*
Maintenance supervision	*0.30*
Patrol (guards)	*0.31*

The remaining overhead costs are widely distributed over the usual administrative and service activities.

Table 7. Distribution of costs among GS, DW, and E processes.

	Percentage of Cost		
	GS	DW	E
Direct Production Cost	90.5	4.2	5.3
Direct Maintenance Cost	95.4	2.0	2.6
Utilities	94.5	4.8	0.7
Total Direct Cost	93.2	4.2	2.6

Two thirds of the GS units at Savannah River have also, subsequently, been shut down. The remaining third is operating at full production rate, currently about 180 tons a year.

With primary recovery cut back to one-third capacity, it has also been possible to curtail operations in the finishing plants at Savannah River. Electrolytic concentration has been shut down completely and moderator-quality heavy water is now produced by distillation. A portion of the distillation plant has, in addition, been set aside for the reworking of diluted heavy water returned from reactors.

LITERATURE CITED

1. Selak, P. J., and J. Finke, *Chem. Eng. Prog.*, 50, 221 (1954).
2. Murphy, G. M., ed., "Production of Heavy Water," National Nuclear Energy Series, III-4F, McGraw-Hill Book Co., New York (1955).
3. Benedict, M., "Survey of Heavy Water Production Processes," *Proc. Intern. Conf. Peaceful Uses Atomic Energy*, Geneva, (1955) 8, 377, (Pub. 1956). P/819.
4. Anon., *Nuclear Power*, 1, 9 (May, 1956).
5. Harteck, P., *Nucleonics*, 14, 9, 97 (1956).
6. USP 2,787,526 "Method of Isotope Separation," Jerome S. Spevack assigned to the United State of America as represented by the Atomic Energy Commission.
7. Weiss, G., *Chem.-Ing.-Tech.*, 30, 7, 433 (1958).
8. Malkov, M. P., et al., "Industrial Separation of Deuterium by Low-Temperature Distillation," *Proc. Second UN Intern. Conf. Peaceful Uses Atomic Energy*, Geneva, 1958, 4, 491 (Pub. 1958). P/2525
9. Roth, E., et al., "Production of Heavy Water in France," ibid., 499. P/1261
10. Akar, P., and G. Simonet, "Industrial Production of Heavy Water by Distillation of Liquid Hydrogen," ibid., 522. P/2583.
11. Bebbington, W. P., and V. R. Thayer, "Concentration of Heavy Water by Distillation and Electrolysis," ibid., 527. P/1065.
12. Gami, D. C., et al., "Production of Heavy Water in India," ibid., 534. P/1649
13. Holmberg, K. E., "Enrichment of Deuterium by Distillation of Dissociable Compounds," ibid 540. P/180.
14. Becker, E. W., et al., "Enrichment of Heavy Water by High-pressure Exchange between Hydrogen and an Aqueous Suspension of a Catalyst," ibid., 543. P/1000
15. Kanda, E., et al., "Experimental Research on the Rectification of Liquid Hydrogen to Obtain Deuterium," ibid., 550. P/1362
16. Bailey, B. M., "Some Aspects of Heavy-Water Production by Distillation of Hydrogen," ibid., 556. P/1068
17. Lehrer, Y., and Y. Weissman, "Design of the Final Stages of Deuterium Producing Plants," ibid., 560. P/1611
18. Deshpande, P. G., and D. C. Gami, "Design of an Electrolytic Plant for the Concentration of Heavy Water," ibid., 568. P/1669

Net positive suction head

A challenging concept of NPSH based on the author's opinion that all the common definitions of NPSH are incorrect in one way or another. Through long experience, the author has developed his own definition which he demonstrates here.

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The centrifugal pump is perhaps the most widely used of any type of equipment in the chemical industry, and at the same time, its principles of operation are probably the least understood. Any discussion of the operation of a centrifugal pump may be conveniently divided into two categories (1) discharge or pressure side, and (2) inlet or suction side. The operation on the discharge or pressure side is generally pretty well understood as about all that is involved can be covered by the simple laws of centrifugal force.

On the other hand, the operation of the pump on the inlet or so-called suction side is not so well understood. In fact, one valid criticism of the published theory of these pumps is the fact that it has failed to consider each side separately. It seems to be commonly thought that a foot of head on one side or the other has the same overall effect but nothing could be further from the truth.

The laws of proportionality used to predict the results of changes in revolutions per minute on quantity, head, B.H.P., and efficiency, hold reasonably well for the discharge side of a pump, but not at all for the so-called suction side.

That this is so can be seen from the curves in Figures 1a and 1b. Figure 1a shows the performance of a typical centrifugal pump for varied revolutions per minute as computed by the well-known relation:

$$Q \sim \text{(rev./min.)}$$
$$H \sim \text{(rev./min.)}^2$$
$$\text{WHP} \sim \text{(rev./min.)}^3$$

Eff., is constant.

In Figure 1a assume the Q. H. relation for 1000 rev./min. was obtained by a test. Then the corresponding relations for 1200 and 1500 rev./min. would be obtained by increasing the value of Q at any point by the ratio 1200/1000; the value of H at the same point by $(1200/1000)^2$, and so on. Assume further that the test at 1000 rev./min. was conducted in such a way that most, if not all, of the head was on the discharge side.

Were actual tests made on this pump at the speeds of 1200 and 1500 rev./min., they would agree reasonably close to the computed results.

Next consider the curves in Figure 1b. These curves were obtained for tests conducted in such a way that the head on the discharge side was negligible and practically all of the head developed was on the so-called suction side and consisted of a suction lift. The curves shown are assumed to be test results at the three speeds.

Now assume that only the test at 1000 rev./min. was available, and it was desired to compute by the laws of proportionality the performance of this pump at speeds of 1200 and 1500 rev./min. These results are shown dotted in Figure 1b and indicate clearly that the laws of proportionality do not apply at all to the operation on the suction side. It is clear that there is a definite limit to the head that can be produced on the suction side of a pump. The maximum value is $H_a - H_{vap}$, and this value can only be approached. It is also clear that no matter how fast you run the pump this limit still holds. It is equally evident that no more water can be discharged than the pressure of the atmosphere (H_a) can force into the eye of the impeller. This would prevent the discharge from increasing indefinitely with increased speed.

Thus, both Q and H are limited by the laws of nature which effectively prevent application of the laws of proportionality. In practice Q can increase with revolutions per minute only so long as the pressure of the atmosphere can supply the required amount of water into the eye of the impeller. Beyond this, some additional positive head must be supplied if flow is to be increased or even maintained. This gives rise to the term "net positive suction head" and represents the actual amount of absolute pressure required at the entrance to the pump to maintain a desired rate of flow.

At this point it might be more exact to simply call this net positive head (NPH) rather than net positive suction head (NPSH), the full meaning of which will be better understood later.

To begin any discussion of (NPSH); it is necessary to understand that the term may have two meanings as (1) NPSH available, and (2) NPSH required. Each must be considered separately.

In this connection, it is also necessary to remember that fluid pressure may be expressed in three ways as (1) gauge, (2) absolute, and (3) vacuum. A pressure gauge reads pressures above that of the atmosphere

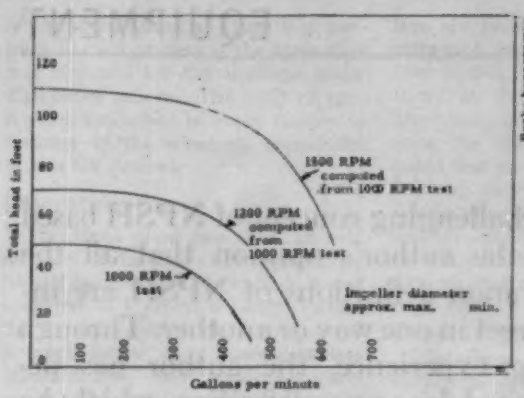


Figure 1a. Here assume the Q.H. relation for 1000 rev./min. was obtained by a test.

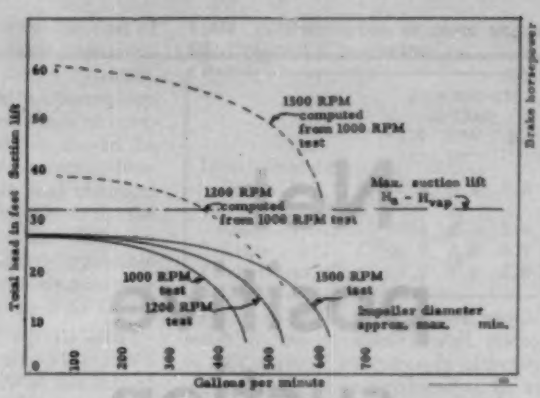


Figure 1b. The curves shown are assumed to be the test results at the three speeds.

NPSH

continued

while a so-called vacuum gauge or suction manometer reads pressures below atmosphere. When a gauge indicates a pressure above atmospheric, it is called "gauge-pressure." The absolute pressure would be the sum of the gauge pressure and the atmospheric pressure.

When a pressure exists below that of the atmosphere it may be designated in one of two ways as (1) a vacuum, or (2) an absolute pressure. Vacuum starts with zero at atmospheric pressure and is measured down while absolute pressure starts at absolute zero and is measured upward. All of this is shown in Figure 2. As vacuum increases absolute pressure decreases.

Consider next the arrangement shown in Figure 3. Here a vertical tank *A* is filled with water to a height *H* above the center line of the nozzle at the end of a short run of horizontal pipe. Water will flow from the tank *A* through the pipe *B* and discharge into the air from the nozzle *C* at the end of pipe *B*. If vertical risers are provided as shown at *D* and *E*, the water level in them will be below that in the tank *A*.

The water level in the riser at *D* will be below that in tank *A* for two reasons: (1) hydraulic losses at entrance and in the pipe *B* up to point *D* and (2) the head required to accelerate the water from the velocity of zero in tank *A* to $C_D = \frac{Q}{A_D}$ at point *D*. This is equal to the velocity head at point *D* which is $\frac{C^{2}}{2g}$.

The water level in the riser at *E* will be still lower than that at *D* due to any hydraulic losses between *D* and *E* and also due to the fact that since the area at *E* is less than at *D* the velocity of flow will be higher since $A_D \times C_D = A_E \times C_E = Q$. The head required to accelerate the flow from C_D to C_E would be

$$\frac{C^{2} - C_D^2}{2g}$$

The pressure head H_E is that which is required to complete the flow from *E* to the end of the nozzle. This would be used to (1) overcome all hydraulic losses from *E* to the end of the nozzle and (2) to accelerate the flow from C_E to the final velocity *V*.

This would be $V^2 - C_E^2$.

-o

This pressure head H_E could be called the net positive head at point *E* and it is responsible for all that may happen between *E* and the end of the nozzle. This is true since the water discharges into the atmosphere which is also the pressure on the water surface in tank *A*. Therefore no difference in pressure is involved and the flow is produced entirely by the head H_E.

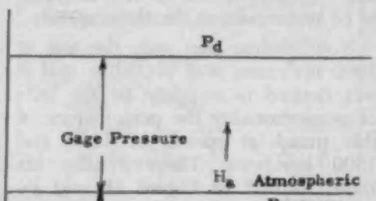


Figure 2. A pressure below that of the atmosphere may be designated in one of two ways.

It is a simple matter to compute the numerical amount of this pressure head if sufficient data are given.

The illustrative example in Problem "A" will make this clear.

Consider next the flow conditions in Figure 4. Here the discharge from the nozzle *C* is into a region of pressure H_F below that of the atmosphere. This would serve to increase the effective head producing flow by the difference between the atmospheric pressure H_{abs} and $\frac{P_F}{\gamma}$ and result in increased flow as represented by

$$V = \sqrt{2g\,(H_a + H - \frac{P_F}{\gamma})}$$

In order to produce the maximum possible flow it is evident that $\frac{P_F}{\gamma}$ should be a minimum. It is not possible in practice to reduce $\frac{P_F}{\gamma}$ to zero since, when it reaches the vapor pressure corresponding to the fluid and its temperature, it would no longer be a liquid and would flash into steam or vapor. In such a case the minimum pressure $\frac{P_F}{\gamma} = H_{vap}$. The velocity (*V*) in this case would be

$$V = \sqrt{2g\,(H_a + H - H_{vap})}$$

and the head producing flow would be $(H_a + H - H_{vap})$ again neglecting hydraulic losses. This is the NPH available under the flow conditions of Figure 4. Since $(H_a + H)$ is the absolute pressure in feet of water, it follows that NPH $= H_{Eabs} - H_{vap}$. In an actual problem involving flow under conditions of Figure 4 where all areas, heads, etc. are known, it

should be possible to compute values of NPH (available) with reasonable accuracy and agreement with practice and plot the same as a function of the rate of flow $Q = AV$.

To find the NPH required to produce a given rate of flow Q we have only to reverse, more or less, the process involved in finding NPH (available). Since we have found by test or computation that a given NPH produces a certain rate of flow, it is evident that this same NPH would be required to produce it. A curve could be plotted showing NPH required as a function of the rate of flow Q.

The application of the foregoing will be made to the solution of a second illustrative problem "B".

In these two illustrative examples it can be seen that for the simple cases shown where all data required are available, it is a comparatively simple matter to compute both the NPH (available) and the NPH (required) for any rate of flow.

As these principles are applied to the centrifugal pump it is impossible to make any satisfactory calculation based on pipe and impeller dimensions for the reason that the areas of the rotating impeller channels, the direction and velocity of the flow, and the hydraulic losses, can only be determined indirectly by a test.

The procedure in such cases to determine the NPH required as a function of the rate of flow is as follows:

Refer to Figure 5: A centrifugal pump is so arranged that the head on the discharge side may be reduced to a value approaching zero, or at least to a point where a decrease of head does not result in increase of flow. Under such conditions nearly all of the head is on the suction side. For such a test the setup should be made so that the static and friction heads on the suction side should be as low as possible. This being the case, the observed rate of flow is about the maximum of which the pump is capable at that rotative speed. The suction line should be provided with a valve which can be closed to provide additional resistance to flow. The test procedure is as follows:

Operate the pump at the desired constant rotative speed, with the suction line valve wide open. Read the suction manometer at entrance to the pump and record the rate of flow corresponding to it. Next close the valve in the suction line so as to give a higher vacuum reading and record the corresponding rate of flow which in general will be less. This should be continued until the highest reading that can be obtained on the suc-

Problem "A"

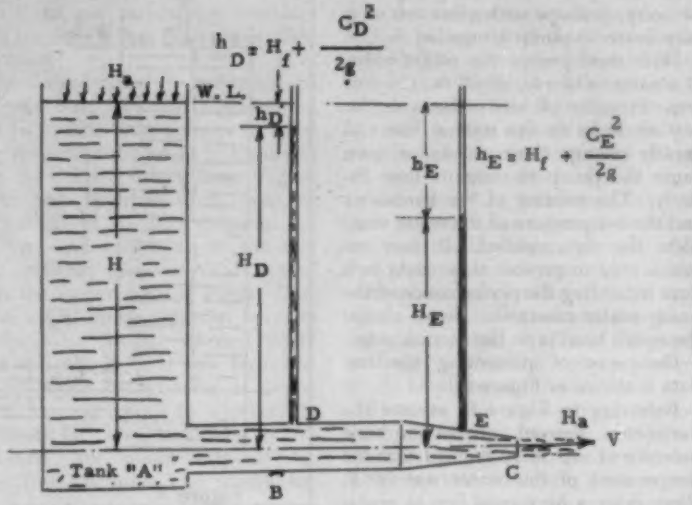


Figure 3.

With the arrangement shown above, assume the following:

$H_a = 33.50$ ft. $\quad H = 10$ ft.

Diameter of pipe at $D = 10$ in. $\quad A_D = 0.545$ sq. ft.

Diameter of pipe at $E = 5$ in. $\quad A_E = 0.1364$ sq. ft.

Diameter of nozzle $= 1$ in. $\quad A_N = 0.00546$ sq. ft.

Assume that the total hydraulic losses to be 0.30 ft. and divided as 0.10 from tank A to point D, 0.10 from D to point E and 0.10 from E to end of the nozzle. Then,

$$Q = A_N \times V = 0.00546 \times \sqrt{2g(10.00 - 0.30)} = 0.1363 \text{ cu.ft./sec.}$$

and

$$C_D = \frac{Q}{A_D} = \frac{0.1363}{0.546} = 2.50 \text{ ft./sec.} \quad \text{and}$$

$$C_E = \frac{Q}{A_E} = \frac{0.1363}{0.546} = 9.95 \text{ ft./sec.} \quad \text{and}$$

$$\frac{C_D^2}{2g} = \frac{2.50^2}{64.4} = 0.0972 \text{ ft.} \quad \text{and}$$

$$\frac{C_E^2}{2g} = \frac{9.95^2}{64.4} = 0.1555 \text{ ft.} \quad \text{and}$$

$$V = \sqrt{2g \times 9.70} = 25.1 \text{ ft./sec.}$$

The water level in the riser at D will stand (10.00 − 0.10 − 0.0972 ft.) = 9.80 ft. above the center line of the nozzle, and the water level in riser at E will stand (9.80 — 0.1 — (1.555 — 0.0972 ft.)) = 8.245 ft. above the center line of the nozzle.

This pressure head at $E = H_E = 8.245$ ft. must complete the flow to the end of the nozzle. This involves overcoming the hydraulic losses between E and the end of the nozzle (0.10 ft.) and accelerating the velocity from its value at E (9.95 ft./sec.) to its value of (V=25.1 ft./sec.) at the end of the nozzle.

The head required to do this would be $\frac{\overline{25.1}^2 - \overline{9.95}^2}{64.4} = 8.23$ ft.

This checks with the value of $H_E = 8.24$ previously found. This represents the NPH available at E under the flow conditions of the problem.

It can also be seen that $H_E = 8.23$ ft. is just what would be required to produce a flow of 0.1363 cu. ft./sec. from the end of the nozzle (diam. 1 in.) and discharge into the atmosphere with losses due to flow of 0.10 ft.

continued

tion manometer is reached. At this point the operation of the pump may be noisy, perhaps with vibration or it may cease to pump altogether.

With most pumps this might occur at a vacuum of say, 26-28 ft., more or less. Presence of air in the water or any air leaks in the suction line can greatly change these values or even cause the pump to drop its flow entirely. The reading of the barometer and the temperature of the water complete the data needed. It now remains only to present these data in a form indicating the performance of the pump under conditions where almost the entire head is on the suction side.

One way of presenting the test data is shown in Figure 6.

Referring to Figure 6, assume the barometer showed an atmospheric pressure of say 33.50 ft., and that the temperature of this water was 70°F. First, draw a horizontal line to represent the atmospheric pressure H_a= 33.50 on the vertical vacuum scale. Next, from the steam tables find the vapor pressure in feet of water corresponding to a temperature of 70°F. This will be about 0.83 ft. Subtract this 0.83 from the value of H_a=33.50 and draw the horizontal line $H_a - H_{vap}$ = 32.67 ft. Now plot the values of Q and the reading of the vacuum gauge obtained on the test, as shown. This curve may be called the maximum vacuum curve in that all points on the curve represent the maximum flow that can be obtained for that vacuum or suction manometer reading. This is so because that is all that the atmospheric pressure can force into the eye of the impeller and at the same time lift the water to that height and overcome all losses due to flow. It is evident that the pressures just inside the impeller eye will be close to the vapor pressures for all points on the maximum vacuum curve.

Consider conditions at a point such as P on the maximum vacuum curve. The ordinate of P represents the reading of the suction manometer for the rate of flow Q. Since at this point the pressure inside the impeller eye is close to the vapor pressure, it follows that the head between P and the line $H_a - H_{vap}$ has been used to force the flow Q into the impeller eye and to overcome all hydraulic losses between the point at which the suction manometer is attached and the eye of the impeller. This is the required NPSH. The reading of the suction manometer will be the difference between the absolute pressure at the point of attachment and the pressure of the atmosphere H_a.

Here we have a relation not unlike a

Problem "B"

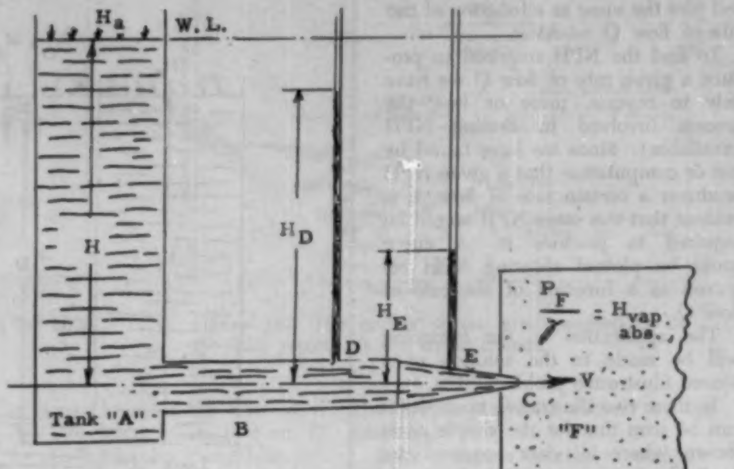


Figure 4.

With the arrangement above, assume the following data:

H=10.00 ft. H_a=33.50 ft.

Temp. water = 70°F. H_{vap}=0.83 ft.

Total hydraulic losses 0.30 ft. divided as before in Problem "A". The pressure in the tank F into which the water discharges is H_{vap} (abs). All pipe sizes are as before.

Under these conditions the head available to produce flow would be $H + H_a - H_f - H_{vap}$=10.00 ft. + 33.50 ft. − 0.30 ft. − 0.83 ft. = 42.37 ft. The velocity of discharge under this head would be $V = \sqrt{2g \times 42.37} = 52.20$ ft./sec. and the rate of flow $Q = A_N \times V = 0.00546 \times 52.2 = 0.2345$ cu. ft./sec. and

$$C_D = \frac{Q}{A_D} = \frac{0.2345 \text{ cu. ft./sec.}}{0.545 \text{ sq. ft.}} = 4.29 \text{ ft./sec.}$$

and

$$C_E = \frac{Q}{A_E} = \frac{0.2345 \text{ cu. ft./sec.}}{0.5364 \text{ sq. ft.}} = 17.2 \text{ ft./sec.}$$

The water level is riser D will stand $10.00 - 0.10 - \frac{4.29^2}{64.4} = 9.61$ ft. above the center line of the nozzle and the water level in riser E will be

$$9.61 - 0.10 - \frac{17.2^2 - 4.29^2}{64.4} = 5.21 \text{ ft. above the center line of the nozzle.}$$

To this value of 5.21 ft. should be added the effective amount of the atmospheric pressure $H_a - H_{vap}$=33.50 ft. − 0.83 ft. = 32.67 ft. This 32.67 ft. represents the absolute pressure head available for overcoming the hydraulic losses between E and the end of the nozzle (H_f=0.10 ft.) and also to accelerate the flow from its value at E of C_E to its final value of V at the end of the nozzle. This would require a head of $\frac{V^2 - C_E^2}{2g} = \frac{52.2^2 - 17.2^2}{64.4} = 37.85$ ft.

Now 33.50 − 0.83 + 5.21 = 37.88 ft. which shows that the head available agrees with that required.

It is also evident that $(H_a + \frac{P_E}{\gamma})$ is the absolute pressure at E. Hence the required net positive head NPH at E is the absolute pressure there minus the vapor pressure.

business transaction in which the initial capital is H_a. This pressure head H_a is expended in doing everything that is done on the suction side as (1) raising the water through the static lift from the lower level up to the point of attachment of the manometer; (2) overcoming all hydraulic losses up to that point; and (3) furnishing the velocity head which amounts to increasing the velocity of flow from zero to that at the point of attachment. Put in the form of an equation $H_a = H_{st} + H_f + \frac{C_s^2}{2_g} + \frac{P_s}{\gamma}$; where $\frac{P_s}{\gamma}$ is the unexpended balance remaining after subtracting $(H_{st} + H_f + \frac{C_s^2}{2_g})$ from H_a. It can be seen that $\frac{P_s}{\gamma}$ is the absolute pressure at the point of attachment. The suction manometer reading, $\frac{P_s}{\gamma} = H_a - (H_{st} - H_f - \frac{C_s^2}{2_g})$, is of course the absolute pressure as in Figure 2.

Since this manometer reads a pressure difference and since one item causing this pressure difference is the velocity head $\frac{C_s^2}{2_g}$, the statement is often made that a suction gauge reads velocity heads while a pressure gauge does not. On the face of it this is confusing but the foregoing analysis should make it evident why this is true insofar as the suction manometer is concerned.

The information obtained by such an NPSH test may be used in several ways. Generally, it is used to specify the amount of NPSH that must be available in a pump installation to permit satisfactory operation at a specified rate of flow. For example, in Figure 6 for a flow of, say, 500 gal./min., an NPSH of at least 10 ft. must be provided. In practice, it is best to provide 4 or 5 ft. more if possible, for safety. It should be remembered that each pump has its own NPSH relation and that there may be some differences between pumps even of the same size and type and made from the same patterns. The performance of pumps on NPSH tests is sensitive to air leaks into the suction line or air present in the water, in solution, or otherwise, and great care must be taken to avoid air leaks. Even a small leak can completely destroy the value of such tests and misleading results may be obtained. Sudden variations in vacuum or rate of flow or surging when operating at high suction lifts may indicate air leaks. It is usually difficult to get satisfactory readings when the flow is less than about 25% of normal.

The data obtained by tests as shown in Figure 6 may be rearranged somewhat for greater convenience to solve other related problems as in Figure 7. Here the NPSH values from Figure 6 have been inverted, so to speak, in that the line $H_a - H_{vap}$ becomes the zero line and values up to the test point vertically give the NPSH curve.

On the upper part of Figure 7 is shown a QH curve obtained by tests on the same pump whose NPSH curve was obtained. It will be noted that reduction of head below about 30 ft. does not result in appreciable increase in Q. This is described by the expression "the pump cuts off" at about 700 gal./min. The reason for

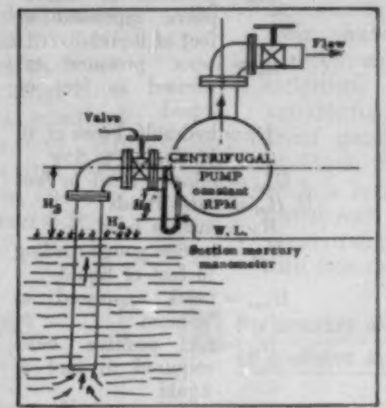


Figure 5. Schematic arrangement of a centrifugal pump installation.

this so-called "cut-off" is due to the fact that at that rate of flow the NPSH curve (Figure 7) crosses the $H_a - H_{vap}$ line as at point A and the required NPSH equals the available NPSH, and the absolute pressure at the impeller eye is therefore H_{vap}. Under such conditions no further increase in flow is possible and it is said that the pump cuts off.

If the temperature of the water were increased from 70°F. to, say, 130°F. the $H_a - H_{vap}$ line would be lowered and the NPSH curve would intersect it as at point B. The effect of this on the QH curve is shown by the dash line and the pump would cut off at about 625 gal./min.

Exactly the same overall results could occur if the pump were raised about 15 ft. above the source of supply. This is also shown in Figure 7 and the new NPSH curve has intersected the $H_a - H_{vap}$ line as at point C.

Proceeding in this way, the points of cutoff can be predicted with fair accuracy for any assumed conditions of water temperature and suction lift. It can be seen that this can also be extended to cover the effect of addition of positive head on the suction in which case the line $H_a - H_{vap}$ is merely raised by the amount of the added suction head, and a new point of cut-off can be determined.

The operating conditions may be such in some cases, where very hot or very volatile liquids are pumped, that the vapor pressure and that of the atmosphere are close together. In such cases, some additional positive head must be supplied at inlet to the pump to begin with. The test procedure would be about as follows:

First, by trial, add enough positive head at inlet to secure satisfactory operation. This can be done by having the pump take its supply from a tank whose upper level is above the pump inlet. The difference in level of the liquid in the tank and the pump inlet can be increased until an increase in such level does not produce appreciable increase in the rate of flow. From here on the test procedure would be about the same as before. Take simultaneously readings of the gauge pressure at the pump inlet and the corresponding rate of flow. Next, close the valve a little so as to reduce somewhat the pressure gauge reading at pump inlet and note the corresponding rate of flow, which will be a little less than before. Continue this until a point is reached where the pump will no longer operate smoothly. There may be noise or vibration, or both, or it may cease to pump altogether. When these data so taken are plotted in the form of a curve the value of the NPH required for any rate of flow can be obtained.

While such a curve could probably not be called a maximum vacuum curve as before, it might perhaps be called a minimum pressure curve and used in the same way. As before, all points on such a curve represent pressures in the eye of the impeller close to the vapor pressure. This is shown in Figure 8.

In Figure 8, assume the liquid flows to the pump by gravity from a tank whose upper level is 23.50 ft. above the centerline of the pump and that a valve is placed in the supply pipe in order to add resistance to flow when desired. The reading of the barometer and temperature of the liquid being known, the values of H_a and H_{vap} may be determined and expressed in feet of the liquid pumped. Starting with the inlet valve wide open, record the pressure at the pump

continued

inlet and the corresponding rate of flow. Next, close the inlet valve a little which will reduce the gauge pressure at the pump inlet and will also reduce the rate of flow. Continue this until sufficient points have been obtained to draw a curve from which the NPH can be obtained.

In Figure 8, H_G represents the reading of a pressure gauge at the pump inlet for a rate of flow of 400 gal./min. To this should be added the difference between H_a and H_{vap} and the sum is the NPH required for that rate of flow.

Thus, the NPSH (available) equals $H_a - H_G - H_{vap}$. But $H_a - H_G$ is equal to the absolute pressure at inlet and, just as before, it is seen that the NPSH (available) equals the absolute pressure minus the vapor pressure. In this manner it has been shown that the NPH or NPSH (available) is always the absolute pressure at inlet — H_{vap}.

An examination of many of the definitions of NPSH (available) as found in many of the published articles involve a velocity head. In most cases this is caused by the incorrect assumption that the NPSH (available) is the same as the total head rather than the absolute pressure head. Referring back to Illustrative example "A" it is clear that the final velocity of flow, V, was produced by exactly the difference between the absolute pressure at E and H_a, or

$$H_E = \frac{P_E}{\gamma} \text{ abs.}$$

The addition or subtraction of the velocity head item would destroy this balance.

A review of most of the published articles on this subject can be confusing. There is no good reason, however, why there should be any difference in the correct definition of NPSH wherever it may be found.

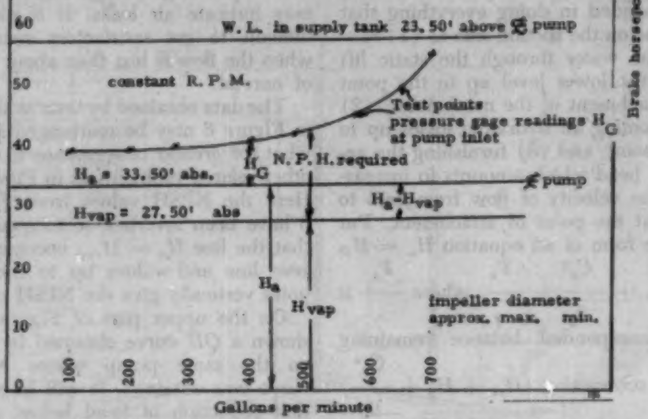


Figure 8. All points on a "minimum pressure curve" represent pressures in the eye of the impeller close to the vapor pressure.

NOTATION

- H_a = pressure of atmosphere expressed in feet of liquid
- H_{vap} = vapor pressure expressed in feet of liquid
- H_f = hydraulic losses of all kinds due to flow
- H_{vel} = velocity head in feet
- H, H_{st} = static heads
- H_S = suction head
- H_{sg} = suction gauge reading in feet of liquid
- H_{vac} = head expressed as vacuum
- H_G = net positive head required in feet of liquid
- P = any pressure
- P_D = pressure at point $_D$
- P_E = pressure at point $_E$
- P_s = suction pressure
- P_d = discharge pressure
- P_g = pressure gauge reading
- *gauge* = reading of pressure gauge above atmospheric
- $\frac{P}{\gamma}$ = pressure expressed in feet of liquid
- vac = vacuum
- abs = absolute pressure
- γ = weight of cubic foot of liquid
- C or V = velocities of flow
- C_E, C_D, etc. = speeds of flow at particular points
- Q = rate of flow in cubic feet per second
- A_D = area of pipe at $_D$
- A_E = area of pipe at $_E$
- A_N = area of nozzle
- r.p.m. = revolutions per minute
- NPH = net positive head (available or required)
- NPSH = net positive suction head (available or required)
- P_F = pressure in tank at discharge from nozzle
- Hg = mercury
- WL = water level

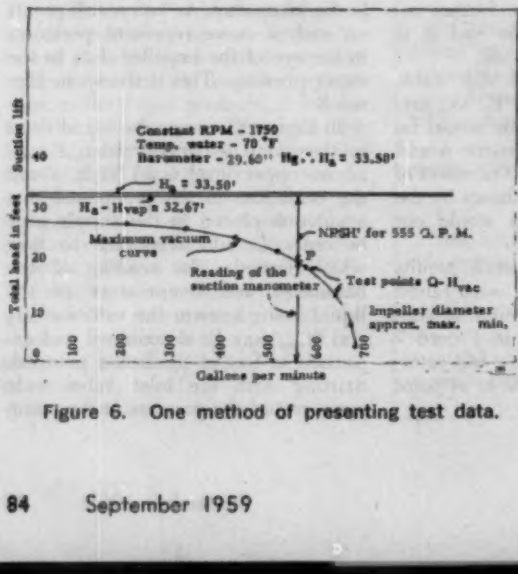


Figure 6. One method of presenting test data.

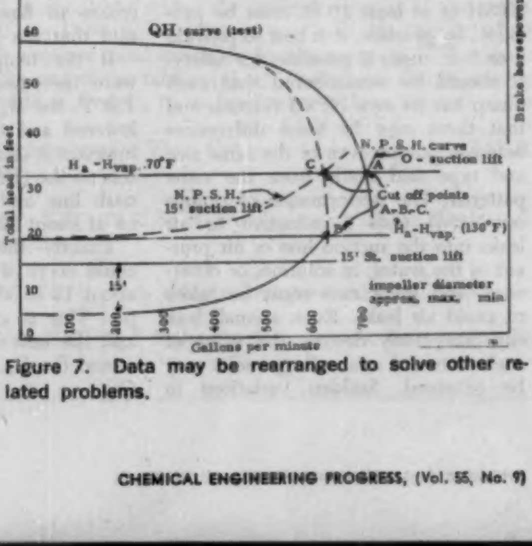


Figure 7. Data may be rearranged to solve other related problems.

CEP COMPUTER PROGRAM abstracts

The Machine Computation Committee of the A.I.Ch.E. is interested in receiving program abstracts.

Once again the Committee wishes to emphasize the three rules for participation in the interchange program:

1) Abstracts submitted for publication must follow the form published in *CEP* (January, 1959) and in the *Guide*.

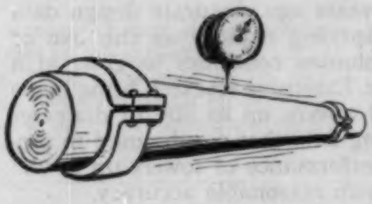
2) Abstracts must be sent to the Machine Computation Committee c/o A.I.Ch.E.

3) All questions relating to published abstracts must be sent to the Committee c/o A.I.Ch.E. in New York.

Critical Shaft Speeds (005)

L. Shaw and M. L. Booy
E. I. du Pont de Nemours & Company, Inc., Engineering Department, Wilmington, Delaware

Description: The program calculates the critical speeds of rotating shafts, either simply supported or overhung at one end, in all modes of vibration. An approximation to the first critical speed is calculated by the Rayleigh or "energy" method. Myklestad's method is then used to calculate the "residual deflection." At the true critical speed the residual deflection is zero. A repetitive technique is used to find the true critical, as well as to find critical speeds higher than the



first. The system geometry, the physical constants of the system, and the number of critical speeds desired must be specified. The program produces an edited output, showing each critical speed requested (in r.p.m.) and listing the residual deflection, speed, etc., for each Myklestad calculation made.

Computer: Univac I, 5 servos.

Program language: A-2 and GP compilers.

Running time: For a shaft of 15 stations, running time is approximately 3 minutes per critical speed.

Comments: The program is limited to shafts with two bearings simply supported or overhung at one end. It assumes no bearing deflection and an instantaneous change in stiffnesss at changes in diameter. It neglects so-called gyroscopic forces.

Availability: A program manual has been written according to A.I.Ch.E. standards and is available for publication if sufficient demand develops.

Box Cooler (007)

Arthur G. McKee & Company
Oil Process Department

Description: This program is designed to calculate the total heat transfer surface and length of pipe required to cool oil of given °API over a specified temperature range, and the pressure drop in the Box Cooler for the above service. The calculations for Box Cooler Design, using this program are carried out by dividing the cooler into a number of sections. The program tests for the type of flow at inlet and outlet conditions and accordingly divides the cooler into turbulent and viscous regions. The entire turbulent region is treated as a single section. The calculations for the viscous region, however, are carried out by dividing this region into a number of smaller sections such that the temperature drop over the entire region is equally distributed over the smaller sections.

The program furnishes design results in alpha-numeric form for the turbulent region and each of the laminar sections besides the over-all design data.

Computer: IBM 650 with alphabetic attachments.

Program language: Bell L_2

Running time: A minimum of four minutes.

Comments: Various physical data, fitted by surfaces, have been incorporated into this program. These surfaces are good for specified ranges of the parameter values under question.

Availability: A program manual has been written and can be made available for publication should sufficient interest develop.

Curve Plotting Routine (013)

H. D. Eddy
Standard Oil Company of California
San Francisco, California

Description: This program reads a set of X and Y data points (a maximum of 500 pairs), orders them by decreasing values of Y, and prints out a graph of either 50 x 100 or 100 x 100 divisions. Any grid character and plotting character may be used.

Computer: IBM 704, 4K or larger.

Program language: Fortran.

Running time: Time for each problem after the binary deck has been loaded is from six to fifteen seconds, depending upon the number of data points and the size of the output sheet called for.

Comments: This program is self-sufficient and can read data from cards or from a tape previously prepared from another 704 problem. It may be used to plot the results of the Tarner calculation.

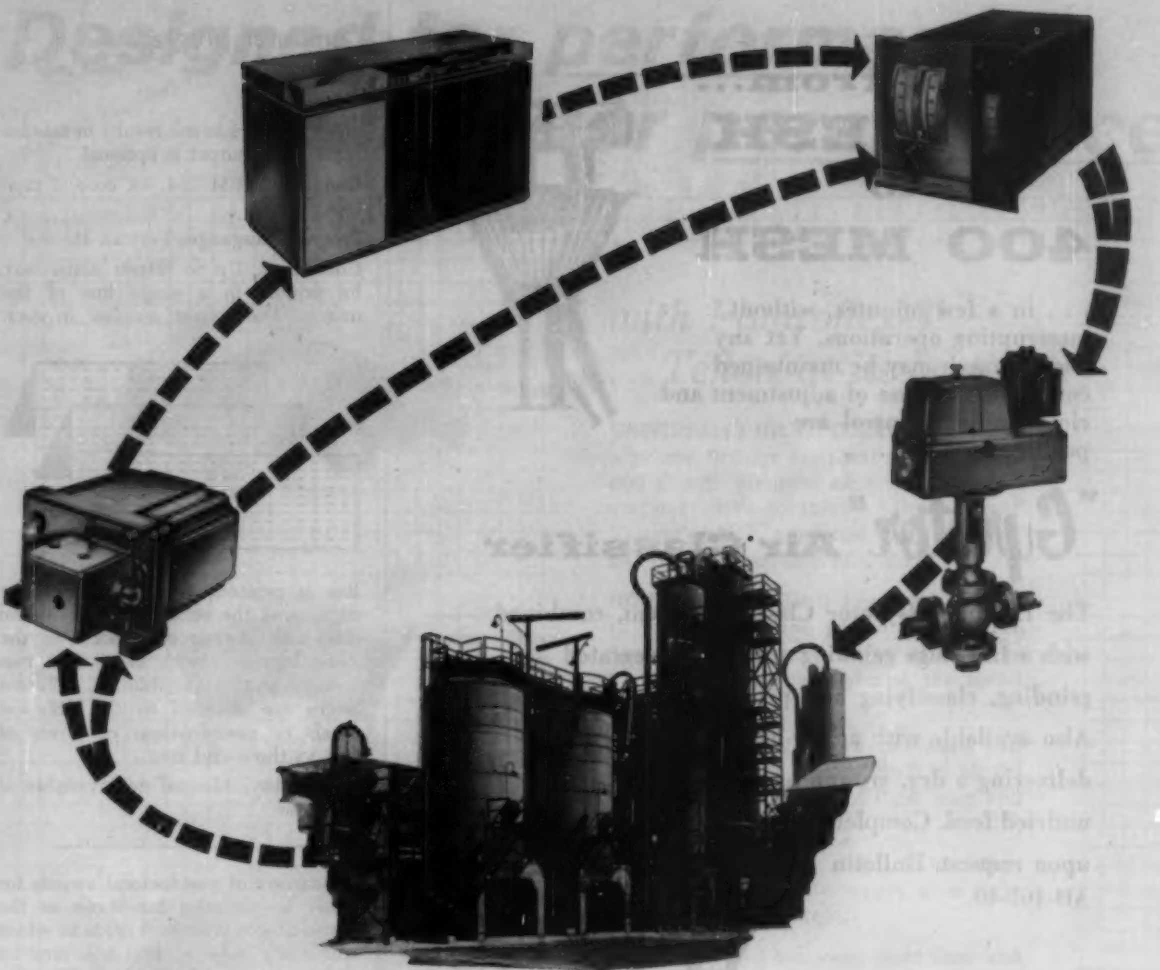
Availability: This program is presently being used for production, and a complete program write-up, less flow diagram, is available at this time. Flow diagrams can be prepared if this program is accepted for publication.

Response Surface Evaluation (025)

Allan W. Dickinson
Monsanto Chemical Company
Applied Mathematics Section
St. Louis, Missouri

Description: The program evaluates a first or second degree polynomial in two, three or four independent vari-

continued on page 88



Computer programs

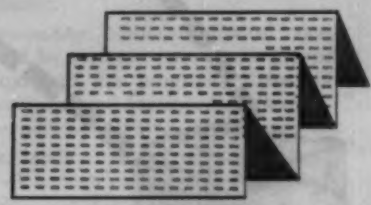
from page 86

ables, and prints the results in tabular form. Tape output is optional.

Computer: IBM 704, 4K core, 1 tape (optional).

Program language: Fortran II.

Comments: Up to fifteen items may be printed in a single line of the matrix. The largest number in each



line is printed with four significant digits and the other numbers in the line with the decimal point in the same location. With more than two independent variables, different pages are devoted to the different levels or combinations of levels of factors three and four.

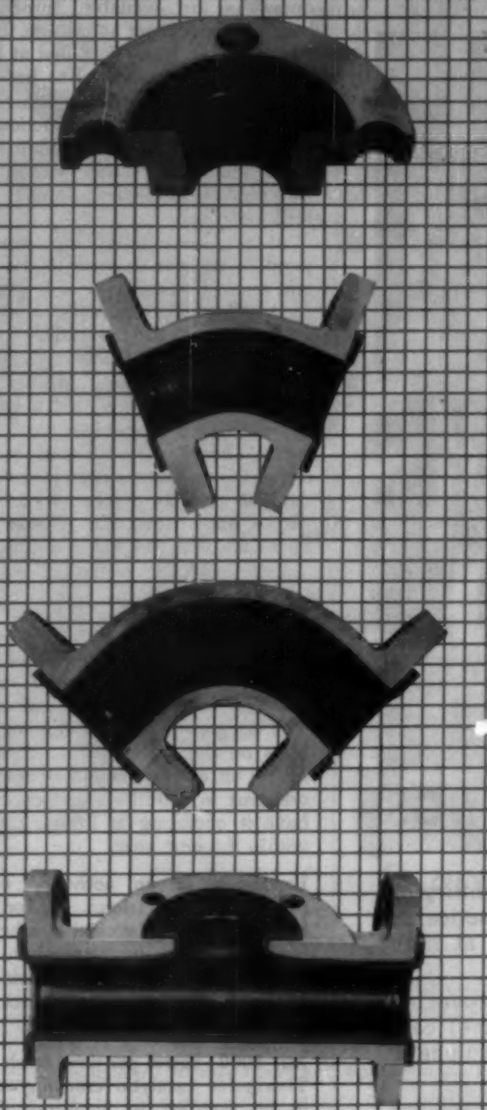
Availability: Manual not available at this time.

A program of postdoctoral awards for study in statistics for those in the physical and biological fields to which statistics can be applied is offered by the University of Chicago. Under a grant from the Rockefeller Foundation, the Department of Statistics at the university offers awards ranging from $3,600 to $5,000 on a nine month basis, or $4,400 to $6,000 on an eleven month basis. Application for the academic year 1960-61 must be made by February 1960.

A 500-ton-a-day oxygen plant will be built at Great Lakes Steel's Ecorse, Michigan, site. An expanded need for oxygen has been created by plans to add oxygen to the open hearth furnaces by roof lances. The new plant will produce 365 million cubic feet of high purity oxygen a month, will be built by Linde Co. (Union Carbide).

A 24 million pound per year maleic anhydride and fumaric acid plant to be built at Fords, New Jersey, by Heyden Newport. Recent industry demands for both materials have outstripped production. This factor, along with increasing use of both chemicals by Heyden Newport, was prime consideration in decision to build the new plant.

Designed for performance
Lined for permanence



with Fluoroflex-T*
... Teflon at its best*

UNIVERSALLY INERT, CORROSION-PROOF pipe and fittings are ideal for service to 500°F with virtually all known chemical and corrosive solutions. Liners are of Fluoroflex-T... a special, high density, non-porous compound of Teflon.

NON-CONTAMINATING Fluoroflex-T liner is formed over the gasket face of the flange—eliminates any contact between the materials being handled and the metal housing.

STREAMLINED—Smooth contours and seamless liner of Fluoroflex-T in all fittings mean a minimum of turbulence and back pressure.

SPACE-SAVING—ASA short radius housings keep pipe runs compact, give tight turns in close quarters.

ECONOMICAL—Chemically inert liner and strong ductile iron housings give *permanent* fitting life—eliminate maintenance and replacement costs.

USEFUL IN ANY STANDARD SYSTEM—Fittings are compatible with any flanged metal, ceramic, plastic or lined piping system in current use.

SEND FOR DATA on Fluoroflex-TS pipe and fittings for complete piping systems. Write for further information to Dept. 302, RESISTOFLEX CORPORATION, Roseland, N. J. Other Plants: Burbank, Calif.; Dallas, Tex.

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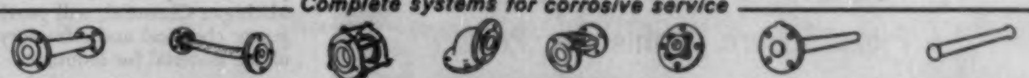
RESISTOFLEX

Complete systems for corrosive service



LINED STEEL PIPE • FLANGED FLEXIBLE HOSE • BELLOWS • ELBOWS • TEES • REDUCERS • DIP PIPES & SPARGERS • LAMINATED PIPE

For more information, turn to Data Service card, circle No. 7

industrial news

Polyethylene resin, film production stepped up

Plans are underway at Dupont for the production of polyethylene film for packaging. At present, limited quantities are available, turned out by a film pilot plant at Orange, Texas. New facilities being installed at Richmond, Va., are expected to be ready early in 1960. Existing buildings formerly used for rayon production will be used, as well as an addition to these buildings, which will operate as a unit of the present Spruance cellophane plant.

At the same time Dupont is expanding its manufacture of polyethlene resin. Construction of a plant at its Victoria, Texas, works, is due to be completed early in 1961.

Also stepping up polyethylene film production is Visking (Union Carbide), which has acquired a site for manufacturing operations near Montreal. The new installation will increase the company's polyethylene film capacity by 50 percent when completed early next year. Market will be to Quebec and the Maritimes.

A plant for the manufacture of ultra-pure silicon metal will be erected near St. Louis, Mo., by Monsanto. The company has been running pilot units on the silicon plant (impurities in the ultra-pure amount to less than one part in 6 billion), and expects to have it operating at design capacity within the next year.

Expansion of an activated carbon plant at Neville Island, Pa. for Pittsburgh Coke & Chemical is scheduled for completion in November. New production equipment is being installed, and alteration of existing facilities is taking place.

An 8000 barrel-per-day fresh feed Thermofor catalytic cracking unit is to be installed in Shamrock Oil & Gas' McKee refinery in the Texas Panhandle. Engineering and construction contract goes to Fluor, with completion of the unit scheduled for next spring.

Start-up of new magnesium oxide plant at Port St. Joe, Florida, by Michigan Chemical, will provide high purity chemical and refractory grades of the material for industry.

For more information, turn to Data Service card, circle No. 12

New paraffin wax plant —design and equipment

Details are now available on Atlantic Refining's new paraffin wax unit in Philadelphia. The plant, which uses the Texaco solvent dewaxing process, is a three-stage methyl ethyl ketone unit, was engineered and built by Badger Manufacturing.

Figure 2. Foreground shows Atlantic's new plant in operation at the Philadelphia refinery.

The three filtering stages of the new unit are dewaxing, repulping, and wax fractionating. The first two stages are normally operated at temperatures on the order of 10 to 20°F, with the repulping stage operating at 10°F above the dewaxing stage. The dewaxed oil product of the first stage is stripped of its solvent content, and provides paraffin oils. The repulp wax mix, containing a fairly low oil content slack wax, is reheated to solution without stripping, and chilled to temperatures of the order of 60°F for charge to the wax fractionation filters. In this stage, the higher melting point hard waxes are recovered as filter cake, while the lower melting point waxes, together with practically all of the oil from the repulp wax mix, appear in the filtrate. The stripped cake, after acid treating and clay percolation, is the fully refined wax product; the filtrate is sweated to crude scale wax, and may be acid treated and clay percolated to a semi-refined wax.

The unit is manifolded in such a way that the wax fractionation filters can be used in repulp services, so that additional scale or semi-refined wax may be made via the two-stage route followed by sweating.

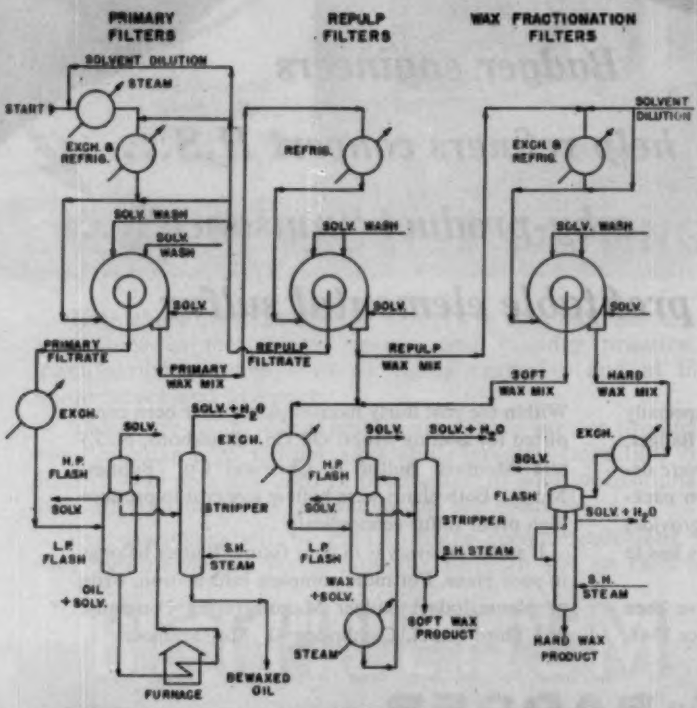


Figure 1. Simplified flow diagram of Atlantic Refining's new paraffin wax plant engineered by Badger.

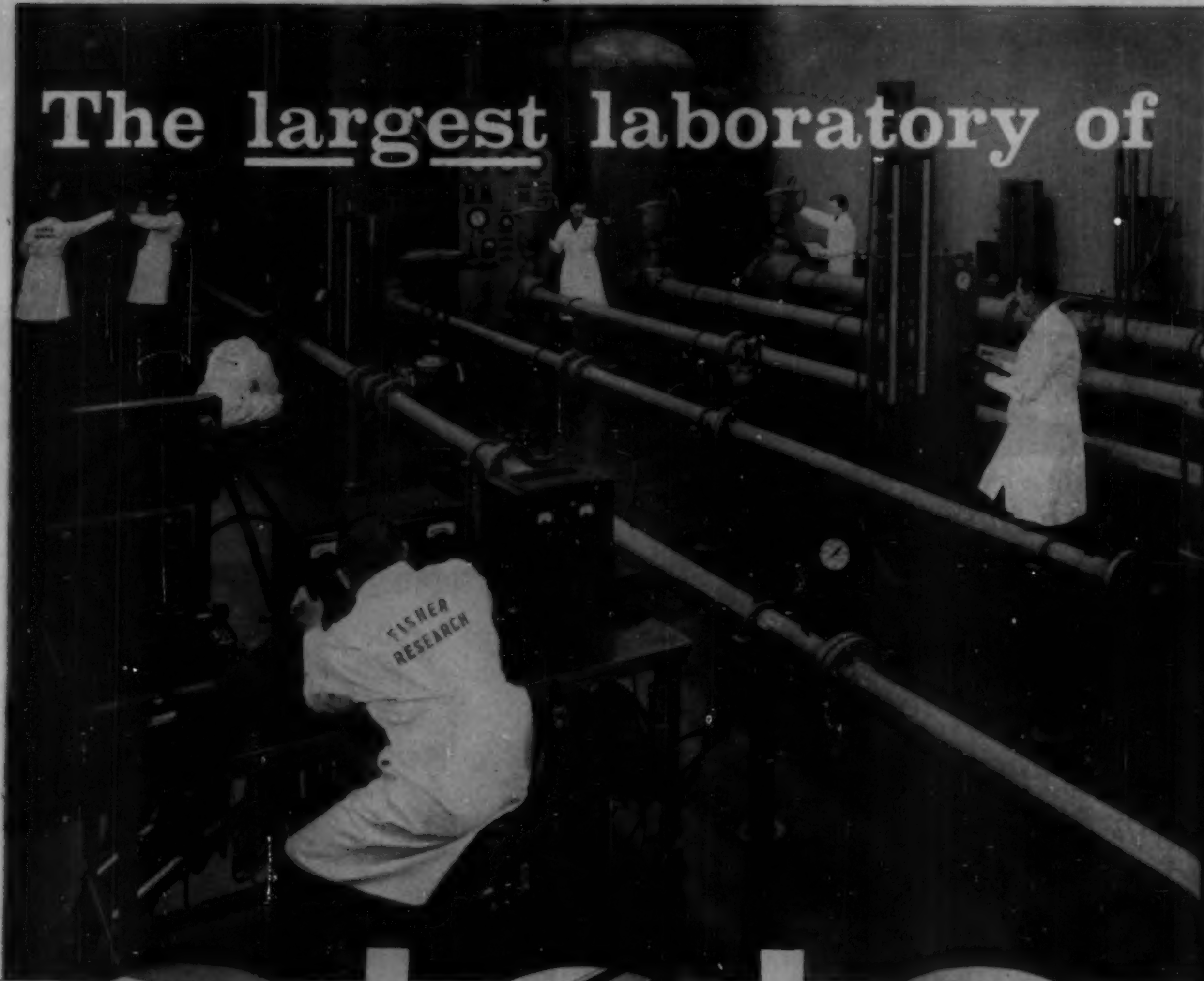
Design features

Production of 0.2% oil content paraffin wax requires that care be taken to hold the oil content of the solvent at a very low level, particularly during the wax deoiling step. In this plant, the natural selectivity of the process for oil and wax is employed to segregate recovered solvent into oil-bearing and oil-lean solvent streams. Oil-lean solvent (0.02 wt. % max. oil content) is recovered in the wax recovery system and is used in the wax fractionation system. Oil-bearing solvent (0.1 wt. % max. oil content) is recovered in the dewaxed oil recovery system, and is used as dilution and wash solvent in the dewaxing-repulp systems.

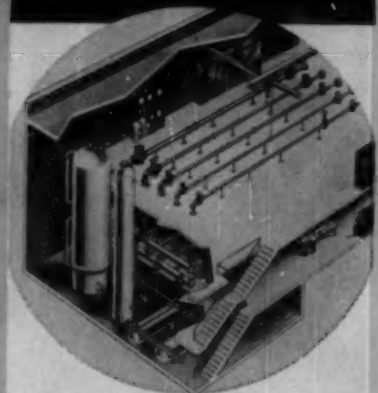
Oil contamination of the solvent recovered in the double-effect dewaxed oil recovery system is controlled in each effect by fractionation using several bubble trays under suitable solvent reflux. A substantial amount of oil is carried overhead also with the last traces of solvent stripped from the dewaxed oil product. The oil contained in this stream is subsequently rejected from the plant as the bottoms from a 25-tray solvent fractionator.

continued on page 96

The largest laboratory of

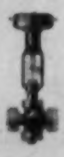


Flowmeters and manometers are just two types of precision equipment used for accurate measurement in this unique laboratory.



Three full stories are devoted to testing and proving the quality of all Fisher equipment.

A Fisher engineer obtaining frequency response data of Fisher equipment under test on an oscillograph.



IF IT FLOWS THROUGH PIPE ANYWHERE IN THE WORLD . . . CHANCES ARE IT'S CONTROLLED BY . . .

Equipment

from page 92

Repulping of slack wax separated in the primary filtration is made more effective by use of a controlled heating and chilling step between filtrations. Slack wax mix is heated to the desired temperature by warm recirculated wax mix and warm solvent additions to obtain partial melting of the wax. This mixture is then chilled in scraped double-pipe chillers to the repulp filtration temperature.

A separate hard wax solvent recovery system is included in the new plant to assure hard wax product quality, and to avoid equipment and product contamination with oil.

The 700 square foot filters are of a new design in which the trunnion bearings are integral with the filter vat, the entire assembly being mounted on a rigid frame.

Centrifugal pumps are used to handle cold wax-solvent slurries at the filter boots. These slurries are said to have been a pumping problem in earlier units, particularly where rotary pumps were used.

For double-pipe exchange and chiller equipment, one-shot grease lubrication of all bearings and automatically controlled continuous oil-mist lubrication of all chain drives has been provided. Lubricating oil is delivered from storage through a circulating system to the gang lubricators at each filter. Refilling of the reservoir at each filter may be accomplished by a simple opening of a valve.

The double-pipe exchanger stands on the unit are equipped with removable inner tubes. This permits convenient replacement of the inside tubes in locations where wear is encountered. As further insurance, both exchanger and chiller scraper blades are provided with stops to limit the wear of blades against the inner tubes.

Exchanger and chiller area

The double-pipe chillers and exchangers are conventional 12-pipe units arranged in two parallel banks, with drive ends facing each other, and with an operating aisle between. The flow through the inner pipes in all cases is wax mix on its way to the filters—primary, repulp, or wax fractionation. The primary wax mix is exchanged against primary filtrate, and the wax mix fed to wax fractionation is exchanged against its filtrate. Each chiller is operated with a flooded recirculation refrigerant system. The

continued on page 98


PRODUCTS
ELECTRODE
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Equipment

from page 96

double pipes in all chillers are inclined slightly from the horizontal to promote rapid recirculation and gas elimination, and to provide for maximum heat transfer rate.

Filter area

Equipment consists of fourteen 11 ft. by 20 ft.-3 in., 700 sq. ft. conventional rotary filters. The chilled wax mix from elevated filter feed tanks flows by gravity into the filter vats under liquid level control. As the drum rotates in the chilled wax mix solution, dewaxed oil and solvent are pulled by vacuum through the filter cloth and drained into filtrate receivers. Simultaneously, the wax cake is progressively built up on the canvas covering. As the wax cake emerges from the oily solution, it is washed by means of solvent sprays, and dried with flue gas under vacuum. At the end of the cycle, the cake is subjected to a slight flue gas pressure, and is blown free of the filter cloth and deflected by a scraper blade into a scroll-type conveyor. The discharge conveyor continuously discharges cake wax from the filter into a vertical boot where it is diluted and melted by warm solvent (or recirculated wax mix) and pumped by open type impeller centrifugal pumps into flue gas-blanketed surge tanks for the successive chilling and filtering operation and/or solvent recovery. The filtrate is continuously pumped from the filtrate receivers by vertical pumps, through exchange, and into flue gas-blanketed surge tanks for charge to solvent recovery and/or for use as dilution and wash solvent.

Solvent recovery system

In this system, solvent is separated from the soft wax, hard wax, and dewaxed oil and returned to storage for reuse. Three separate recovery systems are provided, one for each product.

Solvent is separated from the dewaxed oil by double-effect flash vaporization followed by stripping with super-heated low pressure steam. Both the low-pressure and high-pressure flash towers yield oil-bearing dry solvent overhead. The low-pressure flash tower bottoms (dewaxed oil mix) are heated in a vertical fired furnace and charged to the high-pressure flash tower. The high-pressure flash tower bottoms flow by pressure differential into the stripper tower where superheated 25-lb. steam completes the solvent separation by carrying the remaining traces of solvent, along

with the water vapor, overhead into the solvent decanting tank. The dewaxed oil stripper bottoms are cooled and pumped from the unit for further processing in existing facilities. These are used as base stocks for paraffin oils or as cracking stock. A stripping steam superheating coil is also located in this heater.

The dewaxed oil heater contains 86 vertical tubes in four parallel passes, and is designed for a total heat absorption rate in excess of 64 million B.t.u. per hour. The soft wax and hard wax recovery systems are similar to the dewaxed oil recovery system in that the solvent is separated by flash vaporization followed by stripping with superheated low pressure steam. Steam heaters, however, are used in lieu of a fired furnace, to eliminate the possibility of overheating and cracking the wax. In each system, the solvent is taken overhead, and the wax from the bottom. In all flash and stripping towers solvent reflux is used.

Flue gas and refrigeration systems

Flue gas is generated continuously at the rate of 2,000 SCFH by burning a low sulfur content fuel gas in an explosion-proof submerged combustion flue gas generator. In the event that low sulfur fuel gas is not available, an alternate high-sulfur fuel gas is available which, however, must be previously purified.

Two 42 by 42 by 14 in. Ingersoll-Rand type 2HHE-1 synchronous motor-driven reciprocating vacuum pumps operating at 3.6 lb./sq. in. abs. suction pressure and 19.7 lb./sq. in. abs. discharge pressure are used to maintain the vacuum in the filtrate receivers, and to supply blow-back gas for removal of the dried wax cake from the filter canvas.

Commercial propane is used as a refrigerant. The refrigeration system consists of two centrifugal compressors, propane condensers, propane receiver, high and low-stage flash type economizers, and high and low-stage suction knock-out drums. One 3,000 hp motor-driven compressor and one 2,800 hp turbine-driven compressor are used, each capable of delivering 60% of the maximum total refrigeration requirements. The exhaust steam from the 2,800 hp turbine, along with the steam exhaust from certain steam-driven pumps, satisfies off-site requirements for tank heating.

Condensed from a report by J. R. Ghublikian, Badger Manufacturing, and J. B. Clapham, W. T. Dixon, and D. E. Wigfield, Atlantic Refining.

For more information, turn to Data Service card, circle No. 98

The following 2 pages that appear to be missing are reader service cards and have been removed.

CEP'S DATA SERVICE—Subject guide to advertised products and services

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD

EQUIPMENT *from page 102*

Joints, expansion (p. 129). For temperatures from minus 400 to plus 1,600°F, pressures from full vacuum to 1,000 lb./sq. in. Bulletin 59-50 from Adsco Div., Yuba Consolidated Industries. **Circle 34.**

Mills, grinding, impact (p. 165). Closely-controlled particle size, minimum temperature rise, high abrasion resistance. Data from Entoleter, Div. of Safety Industries. **Circle 35.**

Mixers (p. 109). Six standard models, 1 to 200 hp, special units to 500 hp. Horizontal or vertical drive, mechanical seal or packed stuffing box. Catalog A-19 from Philadelphia Gear. **Circle 96.**

Mixers (p. 141). "Handbook on Mulling" from Simpson Mix-Muller Div., National Engineering. **Circle 74.**

Mixers (p. OBC). Condensed Catalog (Bulletin 109) from Mixing Equipment gives details of all types. **Circle 41-6.**

Mixers, laboratory and small-batch (p. OBC). Bulletin 112 from Mixing Equipment. **Circle 41-5.**

Mixers, portable (p. OBC). 1/6 to 3 hp. Bulletin 108 from Mixing Equipment. **Circle 41-4.**

Mixers, side entering (p. OBC). 1 to 5 hp. Bulletin 104 from Mixing Equipment. **Circle 41-3.**

Mixers, top entering (p. OBC). Propeller types, 1/4 to 3 hp. Bulletin 103 from Mixing Equipment. **Circle 41-2.**

Mixers, top or bottom entering (p. OBC). Turbine, paddle, and propeller types, 1 to 500 hp. Bulletin 102 from Mixing Equipment. **Circle 41-1.**

Nozzles, spray (p. 162). Choice of over 12,000 basic designs. Catalog 24 from Spraying Systems. **Circle 3.**

Packing, column (p. 167). Bulletins and technical data from Packed Column Corp. **Circle 106.**

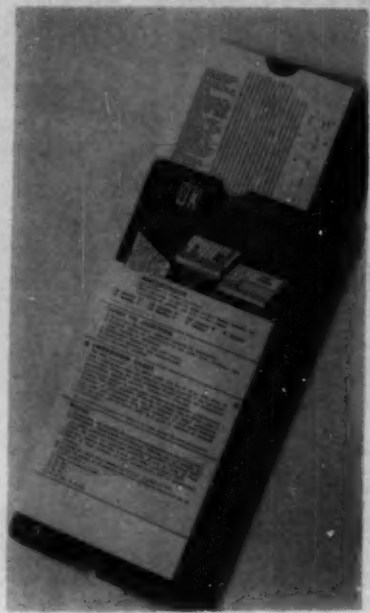
Packing, tower (p. 85). Technical data from U. S. Stoneware on performance of Intalox saddles and metal Pall Rings. **Circle 129.**

Packing, tower (p. 135). Comprehensive Booklet from Harshaw Chemical discusses application of "Tellerettes" to tower packing. **Circle 33.**

Piping, corrosion-resistant (p. 89). For service to 500°F with almost all chemical and corrosive solutions. Data from Resistoflex on "Fluoroflex-T" pipe and fittings, lined with high-density, nonporous Teflon compound. **Circle 7.**

Processor (p. 160). Details from Kontro on the "Ajust-O-Film," centrifugally-wiped, thin-film, pilot plant size processing unit. **Circle 72.**

DEVELOPMENT OF THE MONTH



CORROSION CALCULATOR

(Circle 601 on Data Post Card)

A sliding corrosion calculator, offered by Hoke, Inc., shows preferred materials for 247 different types of corrosives. It covers degree of preference for handling corrosives with aluminum, brass, carbon steel, Inconel, Kel-F, Monel, nickel, nitril rubber, polyethylene, polyvinyl chloride, 304, 316, and 430 stainless steel, Teflon, titanium, many other materials. For a copy of this sliding calculator, Circle 601 on Data Post Card.

Pulverizers (p. 154). The Micronizer, made by Sturtevant Mill, grinds and classifies in single operation in a single chamber. Technical data. **Circle 20.**

Pulverizers (p. 174). Specially designed machines for difficult size reduction work. Data from Gruendler Crusher and Pulverizer. **Circle 70.**

Pumps (p. 115). From 25 to 2,500 hp, pressures to 30,000 lb./sq. in. Data from Aldrich Pump. **Circle 99.**

Pumps, canned (p. 121). Pump and motor in single, leakproof unit. No seals, no stuffing box. Data from Chempump. **Circle 100.**

Pumps, controlled-volume (p. IBC). Catalog 553-1 from Milton Roy is a general introduction to controlled volume pumping. **Circle 42.**

Pumps, plastic (p. 144). No stuffing box or shaft seals. Details from Vanton Pump & Equipment. **Circle 67.**

Pumps, screw (p. 24). Capacities from 1 to 2,000 gal./min., viscosities from 32 to 1 million SSU. Info from Sier-Bath Gear & Pump. **Circle 45.**

Pumps, turbine (p. 99). Capacities to 180 gal./min., discharge pressures to 350 lb./sq. in. gauge, temperatures to 300°F. Booklet from Coffin Turbo Pump. **Circle 98.**

Rectifiers (p. 150). Bulletin from Sel-Rex on semiconductor power conversion equipment and systems. **Circle 4.**

Rotameter, pneumatic, transmitting (p. 140). Details in Bulletin 18N from Schutte and Koerting. **Circle 115.**

Sampler, air (p. 164). For measurement of radioactive material, chemical dusts, smoke, smog. Data from Staplex. **Circle 2.**

Separators, entrainment (p. 4). Bulletin 21 from Otto H. York gives complete details of the "Yorkmesh Demister." **Circle 95.**

Separators, entrainment, line-type (p. 18). High efficiency, high capacity, low pressure drop. Details from Peerless Manufacturing. **Circle 49.**

Strainers (p. 166). Available in 2, 2½, 3, 4, and 6 inch sizes for quick delivery. Technical data from Schutte and Koerting. **Circle 36.**

Tanks (p. 156). New 16-page Catalog from Littleford Bros. **Circle 73.**

Tanks, glass-steel (p. 145). Vertical and horizontal designs from 500 to 35,000 gallons capacity. Bulletin from Pfaudler Permutit. **Circle 126.**

Tanks, stainless (p. 162). Brochure M58 from Puget Sound Fabricators. **Circle 44.**

Thermocouple Extension Wire (p. 168). Bulletin 1200-3 from Claud S. Gordon gives specifications, technical data. **Circle 22.**

Thickeners (p. 11). Bulletin from Eimco covers thickeners, hydroseparators, airlift agitators, reactor-thickeners, slurry mixers. **Circle 61-1.**

Trucks, bulk materials (p. 138). Bulletin 205 from Sprout-Waldron discusses application of pneumatic bulk trucks to process requirements. **Circle 51.**

Valves (p. 94-95). Bulletin AL-8 from Fisher Governor gives comprehensive valve sizing and capacity charts for all Fisher body types and inner valve styles. **Circle 6.**

continued on page 106

CEP'S DATA SERVICE—Subject guide to advertised products and services

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD

EQUIPMENT *from page 104*

Valves (p. 105). New Flo-Ball valve, made by Hydromatics, features 100% flow efficiency, zero leakage, universal mounting, removable flanges, stainless steel construction. Complete Catalog. **Circle 58.**

Valves (p. 111). George W. Dahl Co. specializes in fabrication of special designs. Technical data. **Circle 14.**

Valve, metering (p. 139). Data from Eco Engineering on the new "Gear-Vac" valve for positive metering of viscous media. **Circle 38.**

Valves, plug, jacketed, spring-loaded (p. 150). Bulletin J.57 from Hetherington and Berner. **Circle 26.**

Valves, porcelain, armored (p. 34). Y-valves and angle valves in chemical porcelain armored with fiberglass-reinforced plastic. Data and specifications from Lapp Insulator. **Circle 40.**

Vessels, pressure (p. 152). Any size, type, or metal. Info from Posey Iron Works. **Circle 16.**

Vessels, storage & transport (p. 149). Specially designed for liquid oxygen, nitrogen, hydrogen, helium. Data from Hofman Laboratories. **Circle 128.**

Vibrators, bin (p. 142). Catalog Data from Syntron gives details of pulsating-magnet bin vibrators. **Circle 17.**

Vibrator, bin (p. 161). The "Bin-Flo," made by Bin-Dicator Co., uses small volume of air at low pressure. Technical data. **Circle 21.**

Viscometer (p. 10). Complete details from Brookfield Engineering Labs, on "Viscometran." **Circle 59.**

CEP'S DATA SERVICE—Subject guide to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD

EQUIPMENT

301 Bellows, welded-metal. Belfab Corp. offers free Design Manual and Design Slide Rule for computation of design parameters for welded metal bellows.

302 Centrifuges, laboratory. New 12-page Catalog of laboratory centrifuges, homogenizers, ultra-microtomes, other instruments. Ivan Sorvall, Inc.

303 Centrifuges, pilot-plant. Two new models are offered by Centrico. The SKOG for liquids with solids content up to 20%, the SAOOH for liquid mixtures with up to 5% solids. Technical data.

304 Compressors. Ingersoll-Rand offers new Booklet on "Compressed Air Fundamentals." Much tabular and chart information on variety of pneumatic equipment.

305 Compressors, air. Specifications, diagrams, cross-section drawings, installation data in new 24-page Bulletin A-62 from Joy Mfg.

306 Compressors, gas-engine-driven. Model HRA-T, made by Clark Bros., built in 4, 5, 6, and 8 power cylinder models, hp from 660 to 1,320. Technical data.

307 Computers, analog. Bulletin from George A. Philbrick Researches describes process applications of all types of electronic analog computing instruments.

308 Control System, liquid level. Capacity from 1 to 1,250 gal./min., sizes from 1/4 to 6 in. Installations and operation described in SRBc 37-59 and Bulletin J-170 from OPW-Jordan.

continued on page 108

MATERIALS

355 Anhydride, for epoxy resins. Bulletin 43, "HET Anhydride" and Bulletin 19, "HET Coanhydride Systems for Epoxy Resins," from Hooker Chemical, Durez Plastics Div.

356 Catalyst, nickel-containing. Specifically designed for pretreatment of catalytic reforming feedstocks for contaminant removal, especially nitrogen and sulfur. Data from Universal Oil Products.

357 Catalysts, sulfur recovery. Brochure from Porocel describes use of its activated bauxite catalysts in sulfur recovery by the Claus reaction. Flow diagrams, case histories.

358 Coatings, coal tar epoxy. Compilation of results of 17 tests on corrosion resistance of coal tar epoxy coatings. Bulletin from Amercoat.

359 Corrosion Inhibitor. New "CRC" said to remove rust and contaminants from metals, plastic and painted surfaces, give them durable moisture and corrosive resistance. Data from Corrosion Reaction Consultants.

360 Ketones, symmetrical. Aceto Chemical offers data on group of Di-n-Alkyl Ketones in the 7 to 35 carbon range, some available for first time.

361 Mineral Products. Condensed Catalog from Minerals and Chemicals gives physical and chemical properties of aluminum silicate pigments, Attapulgus clays, activated bauxites, limestone products.

362 Molecular Sieves, chemical-loaded. New Booklet from Linde (Union Carbide) gives uses, outlines actual

continued on page 108

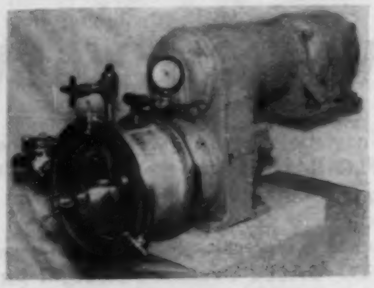
SERVICES

372 Analysis and Development Services. Bulletin 5902 from United States Testing describes its facilities for analysis, development, research, inspection of materials and products.

373 Custom Production Service. Brochure from Commercial Solvents, "Biochemical and Chemical Facilities now Available for Custom Production."

374 Design and Construction, carbon dioxide plants. New Booklet from Girdler Construction Div., Chemetron, gives complete process info, flow diagrams.

DEVELOPMENT OF THE MONTH



LABARATORY HOMOGENIZER

(Circle 603 on Data Post Card)

Cornell Machine offers a small-size "Versator", the DB. The unit, like the larger production units, will homogenize, disperse, or emulsify, and simultaneously deaerate, defoam, or dehydrate a side range of light to viscous formulations. Rate can be controlled from one pint to two gallons per minute. For complete specifications, other technical info, Circle 603 on Data Post Card.

CEP'S DATA SERVICE—Subject guide to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD

EQUIPMENT *from page 106*

309 Controller, temperature. Specification S1010-7 from Minneapolis-Honeywell gives all technical details. For temperatures between minus 50 and plus 1,200°F.

310 Conveyors, pneumatic. Bulletin P-259 from Young Machinery describes individual systems or complete plant installations. In carbon or stainless steels, aluminum, other alloys as required.

311 Cooling Towers. J. F. Pritchard offers Engineering Fact File on its "Lo-Line" water cooling equipment.

312 Ejectors, vacuum. Data Sheet JVS from Jet-Vac describes applications of vacuum ejectors.

314 Equipment, corrosion-resistant. New 64-page Bulletin F-7 from Haveg covers their complete line of corrosion-resistant equipment for the chemical processing industry.

315 Feeders, vibratory. New Bulletin from Eriez Mfg. describes complete line of light and medium duty units. Specifications, capacities.

316 Filters, precoat. Specially designed for removal of slimy, finely-subdivided solids. Available up to 60% drum submergence. Technical data from Komline-Sanderson Engineering.

317 Filter Media. Selection Chart from Purolator Products lists filter media for varying concentrations of more than 125 corrosive agents.

318 Fittings, aluminum. Complete line of aluminum fittings for schedules 10 and 40 pipe now available from Horace T. Potts, Speedline Division. Technical data.

319 Fittings, plastic-lined. Steel fittings, lined with unplasticized vinyl chloride, now available in 8, 10, and 12 in. sizes at Tube Turns Plastics. Technical data.

320 Flow Tubes, Dall, plastic. Thirteen tube sizes from 4 to 48 in. Available from stock. Made of fiberglass-reinforced epoxy or polyester resins with metallic throat linings. Bulletin 115.20.1 from B-I-F Industries.

321 Flowmeter, turbine-type. Capacity up to 15,000 barrels/hour, specially designed for petroleum pipelines. Bulletin OG-417 from Rockwell Mfg. gives technical details.

322 Gauges. Brochure 500SF from Crosby Valve & Gage describes new line of "solid-front" pressure indicating and test gauges. Nylon blow-out back.

323 Generators, inert atmosphere. Bulletin I-459 from Gas Atmospheres includes typical applications, comprehensive flow chart, tables of utilities required.

324 Heat Exchangers. Bulletin B-20 from Struthers Wells covers design and application of line of standard exchangers, available in 6 types and 3 sizes, up to 1,200 sq. ft. of surface.

325 Heat Exchangers, fired. Bulletin 113 from Thermal Research & Engineering describes 5 standard types, gives range of Btu/hr. duty, pressure and temperature ratings, pressure drops.

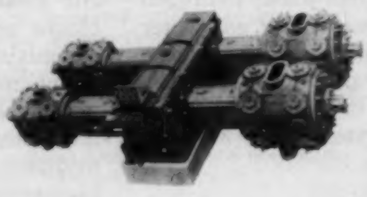
326 Heat Exchangers, impervious graphite. Bulletin HE 642 from Falls Industries gives dimensions, specifications of single, double, multi-pass standard models.

327 Heat Transfer Systems. Bulletin 200 from American Hydrotherm gives details of liquid heat transfer systems. From minus 100 to plus 1,000°F.

328 Heaters, processing. Bulletin DC-1 from Selas describes "Duradiant Clusters," outlines applications to many types of chemical process heating problems.

329 Hose, chemical transfer. Bulletin from Resistoflex gives specifications, applications of Fluoroflex-T Teflon hose and hose assemblies.

DEVELOPMENT OF THE MONTH



NEW PROCESS COMPRESSOR
(Circle 604 on Data Post Card)

Designed for heavy-duty applications in the chemical and petrochemical fields, Clark Bros' new model CJA "Ballanced/Opposed" process compressor is built with 2, 4, or 6 cylinders, and ranges in size from 400 to 1,750 brake horsepower. Rated speed is 450 rev./min. with either electric drive or other prime mover.

The model can be equipped with a wide variety of compressor cylinders, permitting assembly of machines to handle pressures from vacuum to 35,000 lb./sq. in. For Bulletin 160 with detailed technical info and specifications, Circle 604 on Data Post Card.

330 Instruments. New Condensed Catalog from Hays Corp. lists instruments by pressure, flow, temperature, level, gas analysis. Complete specifications of each product.

331 Instruments. New 88-page "Handbook of Hydrostatic Instrumentation" from Petrometer covers its complete line of instruments. Includes 26 pages of engineering data, formulas, tables, and charts.

332 Joints, expansion. Bulletin from Badger Mfg. details nomenclature and selection, info on flanges, liners, covers, temperature ratings.

continued on page 110

MATERIALS *from page 108*

case history in manufacture of vinyl-containing silicone rubber.

363 Packing, process. Bulletin from Flexrock gives details of standard, jacketed, and shredded types, recommended applications, limitations.

364 Plastics. New 12-page Booklet from Monsanto gives technical info on styrene, polyethylene, vinyl chloride molding compounds.

365 Polyglycols. Bulletin "Choosing the Right Polyglycol," from Dow Chemical, lists 40 polyglycols, gives description, formula, molecular weight, specific gravity, viscosity, etc.

366 Polyurethane Rubber. Goodyear Tire & Rubber offers 8-page Brochure on newly-developed Neothane castable polyurethane rubber.

367 Solvents, glycol-ether. Union Carbide Chemicals offers new 40-page Booklet with data on 14 glycol-ether solvents. Physical and chemical properties, derivatives, uses.

368 Sucrose Acetate Isobutyrate. Brochure N-105 from Eastman Chemical Products discusses use as modifying extender in variety of lacquers and melt coatings.

369 Sulfur Dioxide. New Bulletin I-173 from Monsanto Chemical is reference guide for transportation, storage or use of sulfur dioxide.

370 Surface Coatings. Reference Chart from Benjamin Foster Co. gives specifications of wide variety of water and solvent base coatings.

371 Urethane Resin, foaming. Three new Bulletins from Thiokol Chemical give details of new liquid urethane resin prepolymer, formulated with a halogenated hydrocarbon.

For more information, turn to Data Service card, circle No. 96

CEP'S DATA SERVICE—Subject guide to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD

EQUIPMENT *from page 108*

333 Liquid Metering Systems. New electronic controls, registers, readout equipment, now available with the "Pottermeter," pipe-mounted, straight-through metering device. Data from Pottermeter-Bowser Div. of Bowser, Inc.

334 Mill, impact, counter-rotating. New "Contro-Mill" made by Entoleter Div. of Safety Industries, combines double-rotor action with lower rotational speeds to achieve higher impact velocities. Technical Bulletin.

335 Mixer, continuous. New Bulletin 531-A from Nettco describes operation and applications of the "Flomix." Tables of dimensions and motor sizes.

336 Packings, metal. New Bulletin AD-166 from Garlock Packings gives data on selection, application, and installation.

337 Piping, plastic. New 16-page Technical Bulletin CE-80 from American Hard Rubber Co. describes properties, uses of "Ace-Ite," rigid plastic, chemical-resistant pipe.

338 Power Drives, adjustable-speed. New Bulletin GEA-6806 from General Electric covers new 1/4 to 25 hp line of "Polydyne" mechanical adjustable speed drives, gives rating tables, data on accessories.

339 Power Drive, dry fluid. Bulletin A640B from Dodge describes the "Flexidyne" dry fluid drive, claimed to save at least 4% in power over any other fluid drive.

340 Processor. Bulletin 593 from Kontro gives details of the "Ajusto-O-Film" centrifugal processor.

341 Pump, centrifugal, corrosion-resistant. Body, face plates, and impeller of "Cycolac" plastic, shaft and couplings in 316 stainless. Data from Houston Fearless.

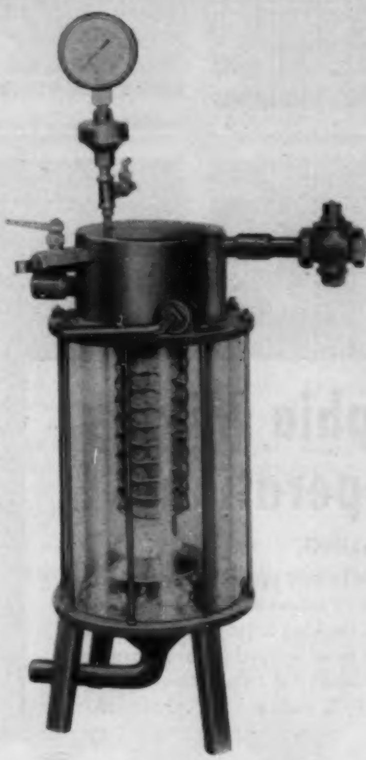
342 Pumps, diaphragm. Bulletin 148 from T. Shriver gives cut-away drawings, dimensions, capacities, power requirements.

343 Pumps, propeller and mixed flow. Bulletin from Layne & Bowler covers models with capacities to 100,000 gal./min.

344 Reactors, glassed-steel. New "E" Series, made by Pfaudler, is available in 50 to 2,000 gallon capacity. Details in Bulletin.

345 Regulator, pneumatic. Precise control of inert gases for testing and calibrating, and for automatic solenoid control of gas systems. Bulletin from Marotta Valve.

DEVELOPMENT OF THE MONTH



REUSABLE CARTRIDGE FILTER

(Circle 602 on Data Post Card)

A new type of filter, introduced by T. Shriver, is said to combine the ease of operation of a cartridge-type filter with the low-cost operation of conventional precoat filters. The unit utilizes a formed-in-place cartridge of cellulose or synthetic fibers on a permanent base.

When the cartridge has become plugged with solids, manual or automatic means are provided for removing the solids from the base and washing them into a small scavenger unit. In the case of liquids, the solids may be semi-dried to reduce liquid loss.

The filter is available in sizes with filtering areas from one to several hundred square feet, in all commonly-used materials of construction. For complete technical data, Circle 602 on Data Post Card.

346 Rotameters, purge. For measurement and control of fluids flowing at low rates. Applicable to both liquids and gases. Bulletin 18P from Schutte and Koerting.

347 Scrubbers, gas. In capacities from 100 to 250,000 cu. ft./min. Bulletin 203-C from Peabody Engineering gives construction details, liquid consumption, gas pressure drop, maintenance, and power consumption.

348 Strainer, porcelain. Body is solid chemical porcelain, end seal is Teflon. Connecting flanges of malleable iron, trim in stainless steel. Lapp Insulator. Technical data.

349 Tanks. In steel or wood, for all process needs. Shop-built, field-erected. Catalog from W. E. Caldwell.

350 Tubing, high-temperature. Special Analysis Memo 114 from Superior Tube gives chemical and physical properties, fabricating properties, applications of tubing made of A-286, special high-temperature alloy.

351 Valves, control. General American Valve offers new "straight-flow" control valve, said to have unrestricted flow in all throttling positions. Technical data.

352 Valves, drain and sampling. Data Unit 355 from Jerguson Gage & Valve gives features, construction details, sizes, ratings, materials.

353 Valves, safety shut-off. Bulletin F-47 from OPW—Jordan gives engineering data, applications of new No. 10 safety shut-off valve, designed for use with hazardous liquids.

354 Viscometer, indicating and recording. Overall accuracy of better than 1% of full scale reading proved in continuous plant applications. Details in Bulletin from Hallikainen Instruments.

A.I.Ch.E. Membership

Brochure—"Know Your Institute"—tells objective aim and benefits to chemical engineers who join this nation-wide organization, includes membership blank. Circle number 600 on Data Post Card.

For more information, turn to Data Service card, circle No. 14

industrial news

Argon recovery by new process

Spencer Chemical unit to turn out 3 million cu. ft./month by the new process.

Just put on stream at Spencer Chemicals' Vicksburg, Mississippi, works, the new argon recovery unit will employ a process which, according to the company, is the first of its type to be built in the United States.

While recovery of argon in air separation plants is a relatively standard operation, Spencers' new unit has as a source of argon a scrubber bottom-fraction that is usually discarded.

The air unit stream is used to oxidize natural gas for the usual production of hydrogen for ammonia synthesis. The hydrogen then is scrubbed free of impurities, including argon, by liquid nitrogen. Argon is contained in the bottoms from this scrubber, and would usually be discarded. Composition at this point is about 14% argon, 33% nitrogen, 39% carbon monoxide, 10% methane, 3% hydrogen, and less than 1% oxygen and krypton.

New process

Scrubber bottoms are cooled to about −200°F, then fed to a column

continued on page 114

Spencer's new argon recovery unit at Vicksburg. Argon is recovered from scrubber bottoms from hydrogen purification unit.

Double expansion in citric

Miles Chemical, and Stauffer, are boosting the supply of citric acid with new facilities. Stauffer's will be in Mexico, in conjunction with Industrias Quimicas de Mexico, S. A.

An additional source of supply of citric acid will be available when large scale production gets underway at Miles Chemical. A $3.6 million expansion being completed by the newly-formed division of Miles Laboratories is expected to bring production up to 15 million pounds annually, marks Miles' first entry into open market sales of citric.

A submerged fermentation and recovery process will be used. The process, originated in 1952 by Miles, has been improved, and a series of patents granted. It blows air through large tanks in which the mold grows on the sugar solution, and is similar to the submerged fermentation process used for antibiotic production. The company claims to be the sole producer today of citric acid by this method.

The addition of 12 new fermentators at the Elkhart, Indiana, plant doubles its present output of citric with provisions for additional growth as necessary. This marks Miles first open market sales of large quantities of citric in a field where formerly only one source of supply was available. In the past, company output has been mostly utilized in a captive market for its own products.

Stauffer plant

Industrias Quimicas de Mexico, S. A., a Stauffer affiliate, has completed plans for the construction of a plant to produce citric also by fermentation. A site has been selected close to a major sugar-producing center to ensure ample raw material supplies. It is anticipated that the new project, on which construction work has begun, will be in full production by next spring. Capacity of the plant, the first fermentation process citric acid unit

continued on page 114

industrial news

New propylene venture by Sun Oil

Part of 120 million pounds a year unit slated for polypropylene production

Construction of a $2 million unit to produce propylene has begun at Sun Oil's Marcus Hook, Pa. refinery. Propylene will be produced by fractionation of propane, ethane, and butane from catalytic cracking plants and gas stabilization units. Two distillation towers, with a combined total of 140 fractionating trays, will comprise the major equipment at the new unit. Each tower, weighing approximately 200 tons, will be 10 feet in diameter and 145 feet high.

Propylene, frequently used as a component of LPG for home heating and cooking, and highly significant today as a constituent of liquid detergents, is in the news mainly on the basis of interest in polypropylene.

Scale model of Sun's new polypropylene unit. Built to 3/8-in. scale, model aids engineers in design problems.

One of the consumers of the propylene produced at the unit will be AviSun with its new facilities for the manufacture of polypropylene. The polypropylene will be converted to polypropylene film at New Castle, Delaware, where equipment to produce 10 million pounds a year is being installed. AviSun, newly formed affiliate of American Viscose and Sun Oil, is also building a pilot plant for manufacturing polypropylene continuous filament and staple fibers.

The Marcus Hook plant will go on stream by the end of the year, according to present schedule, and is designed to produce 120 million pounds of propylene a year.

Argon recovery

from 113

that eliminates krypton and methane in a bottom fraction, and hydrogen overhead. An argon-rich fraction is further distilled to remove nitrogen and carbon monoxide, and the crude argon product is further treated in a chemical purification system. The remaining methane and carbon monoxide react with the oxygen, and any excess oxygen remaining reacts with hydrogen. The CO_2 generated in this reaction is removed by caustic scrubbing, and the H_2O in freeze-out heat exchangers.

Since ammonia plants using the Texaco process in combination with nitrogen scrubbing have this waste stream, the process is expected to be of interest.

Argon produced by this plant will be sold under an exclusive license agreement between Spencer Chemical and Southern Oxygen. The move represents a diversification by the company of its Vicksburg Works, which previously made only nitrogen products.

The unit has a capacity of 3 million cubic feet per month. It was designed and furnished by American Messer Corp., which has also applied for patents on the process.

Expansion in citric

from 113

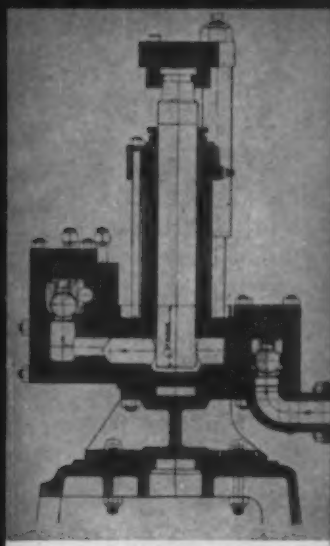
to be built in Mexico, will be adequate to supply the country's total needs.

Stauffer holds a 36% interest in the Mexican firm. The citric acid process, which will be the basis of the new operation, was developed by Stauffer. The Engineering Department of Stauffer will work with Industrias Quimicas in the design and completion of the plant.

Citric acid is finding increasing industrial applications such as for oil drilling, cleaning power plant equipment and metal cleaning, in addition to its continuing use in the beverage, candy, wine, and food industries.

AT DAVISON CHEMICAL LTD.

Aldrich pumps tame highly abrasive, corrosive slurry in high pressure spray drying operation



Special nylon ball valve construction and stainless steel fluid-end eliminates maintenance problems in handling silica gel at 1800 psi.

When Davison Chemical Ltd. built its new plant in Valleyfield, Quebec, for the production of petroleum catalysts, a major problem was to find a pump that (1) had the abrasion and corrosion resistance to stand up in a continuous high pressure process without downtime or excessive maintenance and (2) could maintain the steady pumping pressures necessary to control particle size, density and porosity of the spray dried product.

What was done: Davison Chemical engineers called on Aldrich for help and the result was the special valve design shown. After two years of continuous operation, the Aldrich pumps continue to deliver constant pressure without major overhaul. The General Manager of the plant reports: "We are quite pleased with the performance of these pumps."

How Aldrich can help you: Solving special pumping problems for the chemical industry is the most important work we do. We would welcome the opportunity to discuss your specific problems . . . no matter what the liquid or slurry, or how high the pressures. Standard Aldrich Pumps range from 25 to 2500 hp. Pressures to 30,000 psi. See our insert in Chemical Engineering Catalog for condensed data. Aldrich Pump Company, 20 Gordon Street, Allentown, Pennsylvania.

the toughest pumping problems go to ALDRICH

For more information, turn to Data Service card, circle No. 99

For more information, turn to Data Service card, circle No. 123

institutional news

United Engineering Center Underway

While the final push for meeting the quotas of the fund raising campaign continues, work will soon be underway on the new home of the engineering societies.

October 1 is the date! On that day the first ground will be broken, and the United Engineering Center will be on its way to becoming the imposing structure on the facing page.

But fund raising will not stop. Rising costs must be anticipated, and not even A.I.Ch.E. will rest on its laurels. Although the Institute has met its quota, there is still a lot of money uncollected from local sections that have not reached their quota, and the Institute is going ahead with the campaign to collect as much of this as possible.

The new home of engineering in this country will indeed be an imposing structure in an ideal location on United Nations Plaza in New York. Imposing and, in its own way, symbolizing the large and growing place of engineering in our society today.

For visiting members, the new building could hardly be better situated. Within easy walking distance of both the East Side Airline Terminal and Grand Central Station, and away from the crowded shopping centers of the city, the building is still in the heart of Manhattan, close to hotels, theaters, restaurants, and subways.

A.I.Ch.E. will have the twelfth floor. Central services, library, IBM, etc. for all societies will be centralized on the second floor for economy and efficiency. The first floor will be reserved for exhibitions, meeting rooms, etc. for all societies. In the basement there will be an up-to-date cafeteria for the use of employees and members of all societies. Planners of the building have wisely made provision for future expansion of the building—a must for fast-growing societies like A.I.Ch.E.

The long-time dream of most engineers to have a fitting home for all members of their profession is now a reality.

A seminar course in Chemical Process Design and Evaluation is offered at Stevens Institute of Technology this fall by the Chemistry and Chemical Engineering Department. The course will consist of a series of case studies presented by a group of eminent chemical industry executives.


COMING!
NEW United Engineering Center

UEC BUILDING FACTS — 18 stories high ... 263,067 sq ft, gross, and 179,885 sq ft, net, almost twice as much net space as in the present 39th Street building ... auditorium to seat 450 people ... the world's most complete engineering library ... the Engineering Index, the most comprehensive indexing and abstracting service for engineers ... central services to avoid duplication of costs ... Architects: Shreve, Lamb & Harmon Associates ... Structural engineers: Seeylo, Stevenson, Value & Knecht ... Mechanical and electrical engineers: Jaros, Baum & Bolles ... Contractor: Turner Construction Company.

NEW

UNITED ENGINEERING CENTER

COMING! And indeed it is coming — the new United Engineering Center, the beautiful building as shown, in color, on the reverse side.

Commencement of construction in early fall, 1959 ... Completion of construction by March, 1961 ... Ready for occupancy by July, 1961 ... these are the target dates for the new building.

The New United Engineering Center will rise and stand as a monument to a proud and noble profession. Just as its near neighbor, the United Nations on United Nations Plaza in New York City, stands as a symbol of world co-operation, the new United Engineering Center will stand as a symbol of engineering unity and co-operation in the United States. It will be the greatest center for engineering interests in the world. It will be a structure in which every engineer will have justifiable pride.

There is no question that the building will be built. But the drive for funds cannot be allowed to slow down. This message reaches you at a time when we have just passed the three-quarter mark in our fund campaign. The home stretch — and victory in this united drive — lie in the weeks ahead.

Now is the time for all campaign workers to make sure that all members of each section have at least been contacted. It is the time for all sections of all societies to strive for 100 per cent completion of their quotas. It is the time for those sections which already have reached their money goals to keep trying for 100 per cent membership contributions.

And it is also the time for those engineers who already have contributed to ask themselves: "Have I done my part? Have I given to the best of my ability?"

THE FUTURE HOME OF THESE ENGINEERING ORGANIZATIONS

American Society of Civil Engineers
American Institute of Mining, Metallurgical and Petroleum Engineers
The American Society of Mechanical Engineers
American Institute of Electrical Engineers
American Institute of Chemical Engineers
American Institute of Consulting Engineers
American Institute of Industrial Engineers
American Society of Heating Refrigerating and Air-Conditioning Engineers
American Welding Society
Illuminating Engineering Society
Society of Women Engineers
Engineering Index, Inc.
Engineers' Council for Professional Development
Engineers Joint Council
United Engineering Trustees, Inc.
Welding Research Council

industrial news

Radioactive Krypton-85 caged

New process, developed by Tracerlab, said to provide sources of radioactivity which can be used with far greater margin of safety than heretofore possible.

Trick in the new Tracerlab process consists of making a molecular "cage" for the radioactive gas, krypton-85. This is done by crystallizing hydroquinone in the presence of gaseous krypton-85. As the crystals form, atoms of krypton become trapped within the interlocking network of molecules. The resulting material is called a "clathrate." If the krypton it contains were released, it would expand to approximately thirty times the original volume of the clathrate.

The crystal structure does not interfere with the radiation emitted by the radioactive krypton, but it is said to contain the krypton as effectively as a thick-walled pressure cylinder.

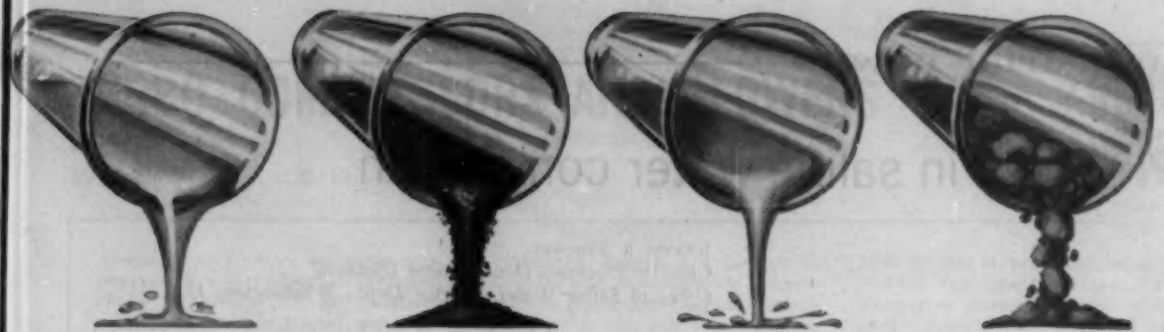
In its gaseous state, krypton-85 is said to possess nearly all of the properties desired in a radioisotope. It is a nearly pure beta emitter with a strength of 695 kev max. Its half life is moderately long (10.3 years) and it is an inert gas like helium or argon and thus cannot be stored or metabolized by the human body like certain other radioisotopes (strontium-90, for example). Up to now, the fact that krypton is a gas has prevented its widespread use. Large quantities cannot be compressed enough to make a small, high-activity source, because this would require use of a thick-walled container which would absorb most of the beta particles emitted.

Use of the newly-developed "clathrate" system eliminates this difficulty. As a bonus, the method is said to be comparatively safe. If the material is spilled, for example, decontamination can be accomplished by pouring water or a ketone solvent over the affected area. This dissolves the clathrate crystals and releases the krypton gas which is rapidly diluted and dissipated into the atmosphere.

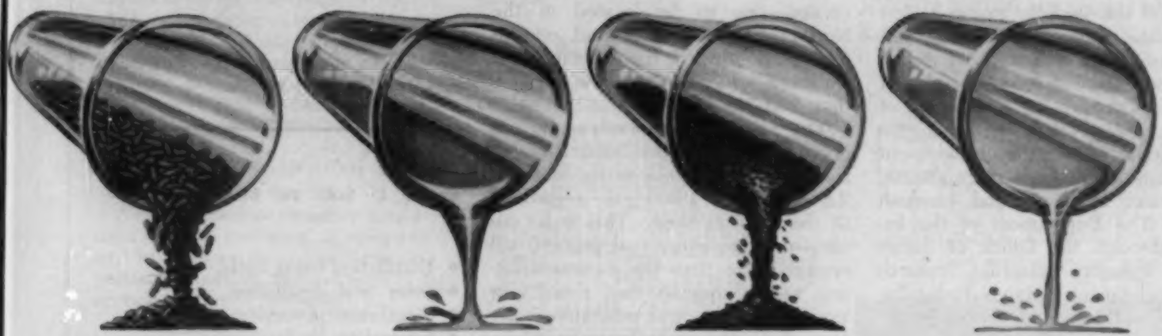
Facilities for the recovery of propylene have been brought on-stream at Texas Butadiene & Chemical's plant near Channelview, Texas. The unit uses the Houdry butane dehydrogenation process utilized by the company in the production of butadiene and butylenes. The propylene will be supplied to other petrochemical producers or used as feedstock to TB&C's aviation alkylate operation.

A substantial interest in a synthetic rubber plant being built by Australia Synthetic Rubber Ltd. has been acquired by Goodyear Tyre & Rubber, Australia. The new plant will have a yearly capacity of 30,000 long tons of styrene-butadiene rubber. Located at Altona, near Melbourne, the $11 million facility is scheduled for completion in July, 1961.

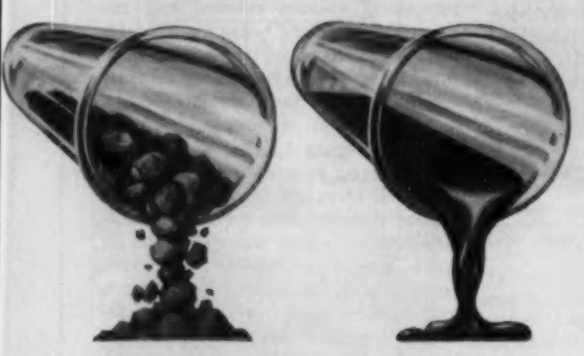
For more information, turn to Data Service card, circle No. 1

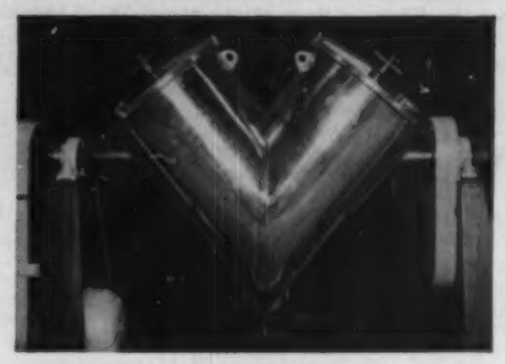


POSSIBILITIES



LIQUID WITH ANY SOLID!





Liquid-Feed bar is easily removed. These features speed cleaning and safeguard against contamination. Sizes range from laboratory models to 50 cu. ft. capacity.

FREE PRE-TEST OFFER. You can preview blending economies at our Laboratory. Pre-testing predicts savings in processing and handling and realistically demonstrates the unique performance of this blender.

Our pre-test facilities for blenders – and also for P-K Vacuum Tumble Dryers – are at your disposal. Send or bring your test materials. For complete information call (Stroudsburg – Hamilton 1-7500) or write George Sweitzer at our East Stroudsburg Headquarters, ..09 Hanson Street.

15

Patterson Kelley

Chemical and Process Equipment Division, East Stroudsburg, Pennsylvania

For more information, turn to Data Service card, circle No. 31

Progress in saline water conversion

JOSEPH J. STROBEL,
Chief of Processes Development Division,
Office of Saline Water, Interior Dept., Washington, D.C.

It is estimated that we will require nearly 600 billion gallons of water per day by 1980, more than double our present demand. Recognizing the need, and the benefits to be gained from saline water conversion, Congress enacted the Saline Water Act in 1952, and extended it by amendment in 1955 to provide for a program of research and development having as its primary objective the development of economical methods of producing fresh water from sea and brackish waters. The Department of the Interior, through the Office of Saline Water, sponsors scientific research and development through Federally-financed contracts and grants, by research in Federal labs, and by stimulating and coordinating private activities in this field.

In 1958, a new law authorized construction and operation of not less than five demonstration plants to test some of the more advanced conversion processes. Three of these plants are to be sea water plants to be located on the West Coast, the East Coast, and the Gulf Coast; the capacities of two of them are to be not less than 1 million gal./day. The other two are for brackish water conversion—one to be located in the Northern Great Plains, and one in the arid Southwest; the capacity of at least one of these is to be not less than 250,000 gal./day.

The minimum thermodynamic energy requirement for separation of fresh water from sea water is about 2.8 KWH per 1,000 gal., regardless of the method used. This is for an ideal process: every real process will require more than the minimum figure, and it appears that about four times this theoretical minimum is the best that one could hope to attain. Thus, the energy requirement alone for any real sea water process will not be less than 12 KWH per 1,000 gal.

Thirty conversion processes were listed for study: this list was then narrowed down to approximately sixteen. The field has subsequently been further reduced and may be classified under five types:

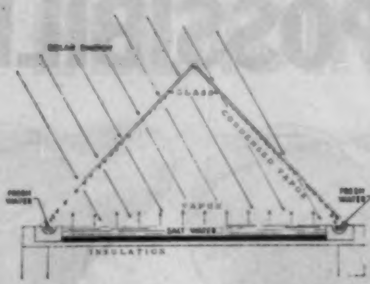


Figure 1. Solar still of simple design.

- Distillation using fuels;
- Solar heat distillation;
- Membrane processes;
- Separation by freezing;
- Other chemical, electrical, or physical conversion methods.

Solar distillation

Major problem in solar distillation is reduction of equipment costs. Prototypes of various existing and improved designs are being installed for further development by Battelle Institute at a research station recently established near Port Orange, Florida.

A solar still of simple design is shown in Figure 1. This is a shallow, glass-covered evaporating tray. Solar energy is absorbed on the black bottom of the tray; this results in distillation of the saline water into the air space above the liquid. The vapor condenses on the sloping glass covers, and distilled water runs down the inside of the glass sheets to channels at the edges of the tray.

Several types of solar still are being evaluated at the Florida site. First pilot plant to be constructed there is a deep-basin still with a 2,500 sq. ft. area. Designer was George Lof. Two other prototypes, one of 2,500 sq. ft. and the other of 500 sq. ft. make extensive use of plastics and are of designs proposed by Du Pont.

Freezing processes

Use of freezing techniques has cer-

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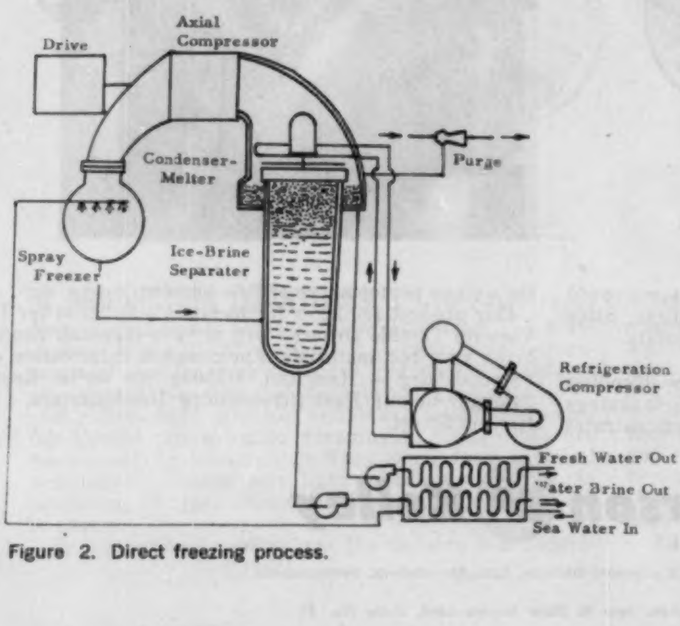


Figure 2. Direct freezing process.

TURBO-COMPRESSORS AND BLOWERS

2500 cfm and up

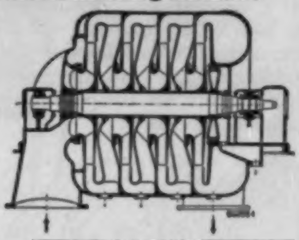
By Eugen P. Eicher, M.E., Brown Boveri Corp.

Brown Boveri offers complete compressor sets including compressor, choice of drives and all auxiliary equipment. Brown Boveri manufactures all the components, assembles and tests the complete sets in their own workshops and assumes full responsibility for the complete unit.

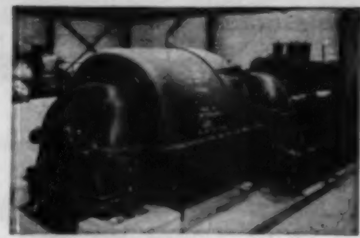
Compressors include a full range of centrifugal and axial types. Drives include steam turbines, gas turbines, expander turbines and electric motors. (Where hot waste gases are available, for example, a combination of motor-generator and exhaust-gas expander turbine drives has reduced power costs 60 to 70%.) Auxiliary equipment includes gear sets, pressure and volume regulators, air and gas coolers and complete electrical control systems.

Brown Boveri compressor sets are used by many leading U. S. companies and are backed by engineering skill, product reliability, and complete U. S. service staff and facilities.

2500 to 175,000 cfm at up to 60 psi*
Uncooled centrifugal blowers



Four-stage centrifugal compressor.



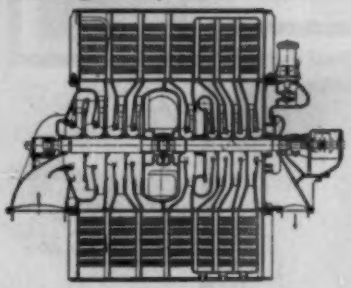
One of two 40,000 cfm centrifugal blowers with steam turbine drive in a copper conversion plant, Arizona.

First developed by Brown Boveri. Advantages over reciprocating compressors in the above ranges: lower cost, higher efficiency, less maintenance, less floor space and *clean, oil-free air.*

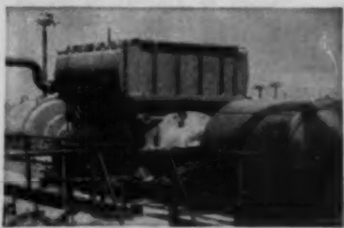
Standard designs are for air or non-poisonous, non-corrosive and non-explosive gases. Stainless steel impellers, shafts, etc. are available for corrosive gases. High-pressure casings and oil type sealing glands are available for higher pressures.

Applications: Blast furnaces, converters, coke ovens, gas distribution, process air and gases, air separation plants, sewage aeration, tunnel ventilation.

5000 to 80,000 cfm at 60 to 120 psi*
Internally-cooled "Isotherm" centrifugal compressors



Nine-stage "Isotherm" compressor with anti-surge power-recovery turbine.



"Isotherm" compressor driven by a synchronous motor (left) and a waste-gas recovery turbine (right) at a California chemical plant.

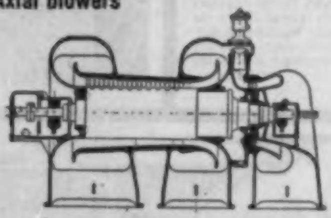
Highest inherent efficiency. Ten basic models with 6 to 9 stages per casing. Impeller diameters from approx. 1 ft. to 4 ft. The larger models include a built-in power-recovery turbine to allow running at loads below the surge limit.

Stainless steel impellers, shafts, etc. are available. For discharge pressures higher than 120 psi, "Isotherm" compressors are followed by an uncooled centrifugal compressor or other booster.

Drives: Four-pole synchronous motors are generally preferred for 1500 hp and larger units, other type motors for smaller sizes. Speed-increasing gears are used with all motor drives. Variable-speed steam or gas turbines are direct coupled.

The reliability of "Isotherm" compressors is proved by hundreds of installations in mines, shipyards, chemical process plants, air liquefying plants, aerodynamics laboratories.

10,000 to 500,000 cfm at up to 80 psi*
Axial blowers



Ten-stage axial compressor with anti-surge power recovery turbine.

Axial blower, steam turbine drive, supplying 70,000 cfm of air for a blast furnace.

Substantially more efficient than centrifugal units for large air volumes where adequate pressure can be delivered with a single unit and without cooling. The higher efficiency allows smaller and better drives and lower cost. A power-recovery turbine may be built in to permit operation at volumes below the surge limit.

Drives. Steam turbines allow simple, automatic control through Brown Boveri pressure-oil governors with pressure or volume regulator. Brown Boveri gas turbines and electric motor drives of all types are also available.

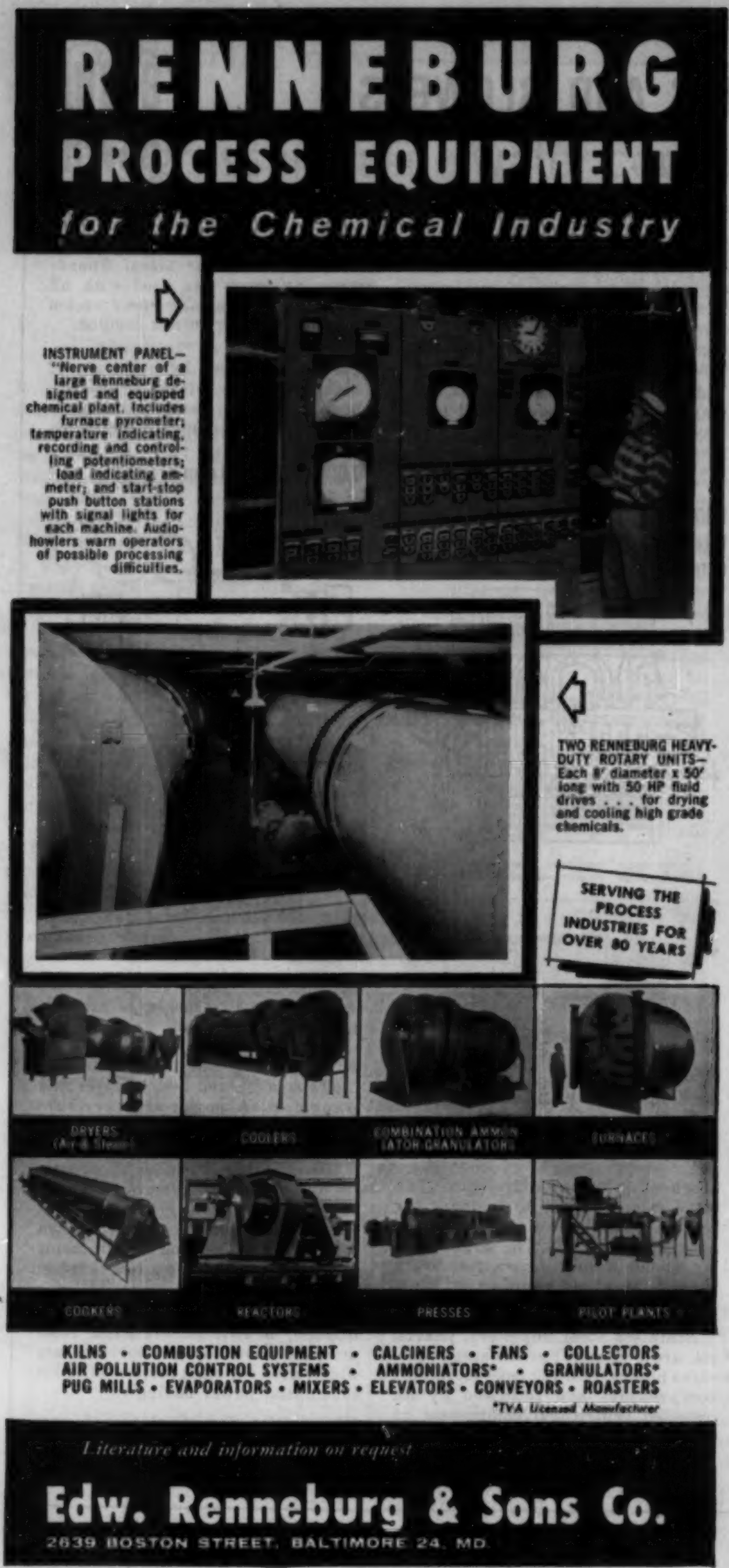
Applications: Gas turbines, wind tunnels and chemical plants. In Europe, Brown Boveri axial compressors driven by gas turbines are widely used for blast furnace air with substantial power savings.

**Capacities for single machines. Higher discharge pressures can be obtained by combining various types of equipment in series.*

BROWN BOVERI

U. S. Sales and Engineering: Brown Boveri Corp., Dept CP9, 19 Rector Street, New York 6, N. Y. Agents in 27 U. S. cities.

For more information, turn to Data Service card, circle No. 68



Saline water

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tain inherent advantages, such as a lesser tendency towards scaling and corrosion because of the low temperature involved, and the lower value of the heat of fusion as compared to the heat of vaporization. Freezing processes can also be operated at low temperature differentials.

Figure 2 illustrates one version of a promising process being investigated by the Carrier Corp. Sea Water, cooled to 32°F. in the heat exchanger, is dispersed to evaporate a sufficient quantity of water to produce an ice-brine slush. The slush flows to a separation column, and the concentrated brine is pumped through the heat exchanger to waste. The ice goes to the top of the column, and a scraper pushes it to the side. The vapor formed in the freezing operation is compressed to a higher pressure and condenses on the ice. The condensed vapor melts the ice, and the melted ice becomes the potable water product.

The major technical problems in this system are said to be removal of the occluded brine from the ice crystals with a minimum loss of fresh water, and satisfactory operation of the freezer. Equipment of this type has successfully produced 100 lb./hour of ice from sea water. Carrier, under OSW contract, is presently building a 15,000 gal./day pilot plant incorporating all components of the complete process.

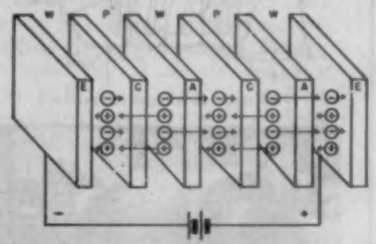

Figure 3. Electrodialysis—schematic diagram.

Another approach, direct freezing—secondary refrigerant, is now being investigated at Cornell University. In this cycle, an immiscible refrigerant, such as butane, is vaporized in direct contact with salt water to form ice. The butane vapor and ice crystals rise to the top of the salt solution. The butane gas is withdrawn and compressed, and the heat of compres-

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Saline water

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sion is utilized to melt the ice after it has been washed free of salt. Laboratory results are said to be promising.

Membrane processes—electrodialysis

An electrodialysis cell, shown schematically in Figure 3, consists of a sandwich of alternating cation and anion permeable membranes. On the application of an electric current, cations pass through the cation membranes, whereas the anions move in the opposite direction through the

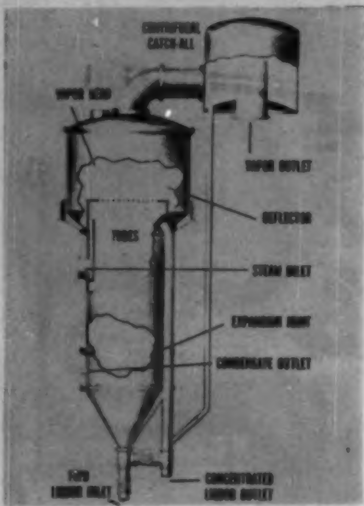

Figure 4. Schematic diagram of long tube evaporator.

anion membrane. Thus, the water passing between alternate membrane pairs is depleted of salt, while that passing through the intervening pairs is enriched.

Electrodialysis equipment, fabricated by Ionics, Inc., has been tested on brackish water in Arizona and South Dakota. In each test, the salt content of the water was reduced to about 350 ppm; no indication of chemical deterioration of the resins in the membrane was evident.

The Office of Saline Water now has a general program of research and development in electrodialysis under way at the Bureau of Reclamation Labs, Denver, Colorado. Various membranes are being tested, and studies are being made of possible improvements in cell design.

In June of this year, an electrodialysis process was selected for the first brackish water demonstration plant. It will be designed to convert

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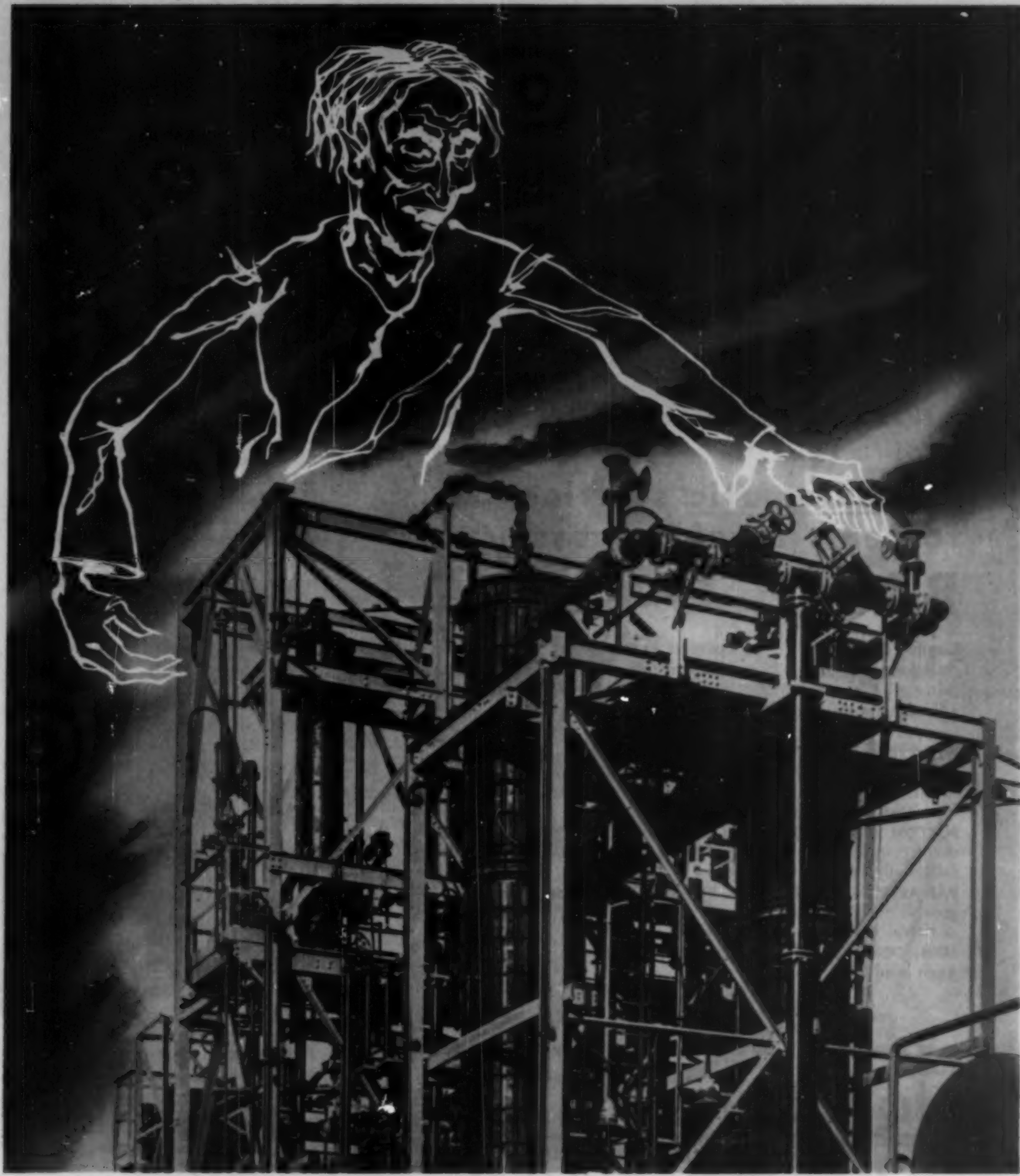

HAVEG - FIRST IN *Engineered* PLASTICS®

Saline water

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brackish water into fresh at a rate of at least 250,000 gal./day, and will be located either in the Northern Great Plains, or in the Southwest.

Distillation

The long-tube LTV evaporator, Figure 4, is a vertical nest of tubes with the heating steam outside, and the liquor inside. The feed enters at the bottom and starts to boil part way up the tubes. The evolution of vapor gives a very high velocity to the mixture. As a result, the heat transfer coefficients obtained are quite satisfactory, ranging from about 200 to 1,000 B.T.U./ hr./sq. ft./F°. The top of the tube bundle is surmounted by a vapor-liquid disengaging space. The liquor passes only once through the tubes of any effect, and no liquor level is maintained in the vapor head. Thus, the residence time in any effect is only a few seconds. The evaporators can also be operated in a reverse

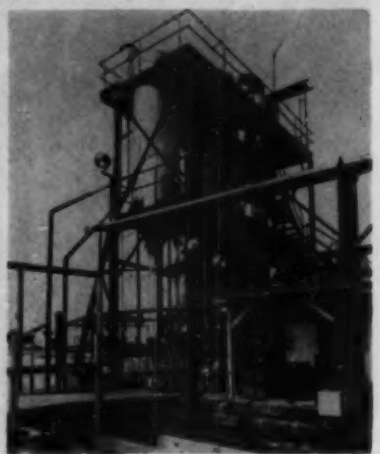

Figure 5. Long tube vertical test installation at Harbor Island, North Carolina.

manner, with the liquid being evaporated flowing down the tubes with the vapor separation space at the bottom.

A means proposed for practical control of scale is seeding with sludge consisting of scale components. The seeding is accomplished by circulating solid particles of the scaling components in suspension in the evaporating liquid. The theory is that the scale-forming salts, which are on the verge of precipitation from the mother liquor, will deposit out upon its own kind rather than on a foreign surface

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Saline water

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such as the walls of the evaporator tubes. A test installation built by Whiting Corp., at Harbor Island, North Carolina, to prove out this system is shown in Figure 5. It consists of two forced circulation (FC) evaporators connected to a small (7-tube) long-tube vertical evaporator. The FC evaporators are used to concentrate the sea water to any desired concentration, and to prepare the sludge for the scale-control tests.

Favorable results have been obtained in the operation of this equipment at International Nickel's station at Harbor Island, N. C. A workable cycle has been established, and the sludge recirculation system has been operated successfully to control magnesium hydroxide scale. Also, results to date indicate that mild steel can be used in a number of evaporator effects.

On March 2 of this year, this LTV process was chosen by the Interior Department as the one to be used for the first demonstration plant. This will be a sea water conversion plant with a design capacity of 1 million gal./day. Preliminary designs are now being made, based on the research and development at Harbor Island. Freeport, Texas, has been selected as the site.

Multi-stage flash distillation

In this system, sea water feed is heated progressively to a temperature

Figure 6. Sea water evaporators at Kuwait, Persian Gulf.

of about 180°F, and then flashed into a number of successive chambers operating under progressively lower pressure. The flashed vapor from each stage is condensed by heat exchange with the incoming sea water feed. Final heating of the sea water before flashing takes place in a salt water heater. Figure 6 shows a 4-stage plant of this type recently completed by Westinghouse at Kuwait on the Persian Gulf.

On May 14, 1959, selection of this process was announced for the second

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Saline water

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sea water conversion plant. This will be a 1 million gal./day installation located on the West Coast. Heat for the plant may come from an AEC experimental process heat reactor built at the same location.

Economics

Conversion costs are gradually being reduced. At the same time, the cost of obtaining water from natural sources is rising. It is believed that, if the cost of converted water can be brought to as low as a dollar per 1,000 gallons, a number of industrial uses will be made. If it can be further reduced to from 50 to 60 cents per 1,000 gallons, then municipal uses, especially to supplement existing supplies, can be expected. Costs of water from the brackish water plants can be expected to be lower. Converting saline water for irrigation uses is a more

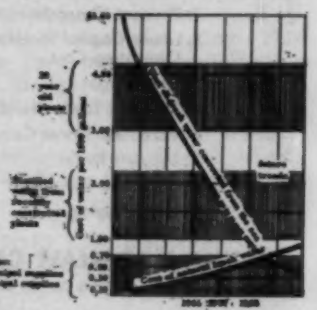


Figure 7. Cost of converted sea water.

difficult problem, since costs for the water must be reduced to as low as 12-15 cents per 1,000 gallons. The demonstration plants are expected to produce water in the dollar per 1,000 gallon range. Present cost trends are illustrated in Figure 7.

Condensed from a talk "Progress in Saline Water Conversion," before a meeting of the National Capitol Section of A.I.Ch.E. on July 20, 1959.

Marketing of a special insoluble sulphur will be done by a joint company just formed by Stauffer Chemical and Kali-Chemie A.G. A plant to be built at Hanover, Germany, it is anticipated, will be in production by January 1960.

The anhydrous lithium chloride plant of American Potash & Chemical has gone into full production at Henderson, Nevada. It will be used in metal products manufacturing, as well as other industrial applications.

SPROUT-WALDRON

SW Pointers

for Mixing and Blending • Size Reduction • Pelleting and Densifying • Size Classification • Bulk Materials Handling

Published in the interest of better processing by Sprout, Waldron & Co., Inc., Muncy, Pa.

One of five Sprout-Waldron Pneumatic Aluminum Bulk Trucks for handling polystyrene pellets in Cosden Petroleum's new "curb service marketing" delivery concept. Note Cosden's modern 32,000 barrel custom refinery in background.

SPROUT-WALDRON BULK TRUCK HANDLES POLYSTYRENE PELLETS

A recent announcement by officials at Cosden Petroleum Corporation, Big Spring, Texas of a new delivery concept, "curb service marketing" is arousing considerable interest throughout the plastic industries. The revolutionary marketing plan involves a delivery of polystrene pellets by special highway transports direct from the purchasing plant to the customer.

The key to the new concept is a group of five 28' pneumatic aluminum bulk trailer units designed and built by Sprout-Waldron. Each of these trailers has a capacity of 1,182 cubic feet which is equivalent to 34,000 lbs. of polystyrene pellets. The high powered unloading system permits delivery to the customer at the rate of 30 tons per hour. Delivery and storage in bulk cuts down on fringe expenses such as unloading, warehousing, multiple handling and contamination. Bulk storage also permits instant inventory determination. Storage bins can be located at the most suitable point in the plant since the pneumatic unloading system built into the trucks permits delivery anywhere a pipe can be run.

Recent completion of the new polystyrene plant is said to make Cosden Petroleum the first producer able to integrate all phases in the manufacture of this basic material. Both general purpose crystal polystyrene and high impact polystyrene are being produced. The styrene monomer used in manufacturing polystyrene is produced in an adjacent plant also owned and operated by Cosden.

For more information on how Sprout-Waldron pneumatic bulk trucks may fit your application, write for Bulletin 205.

COP/102

For more information, turn to Data Service card, circle No. 51

industrial news

A 30 percent expansion in electrolytic manganese facilties at Foote Mineral is in the works, with completion expected by the first of 1960. The new construction at the larger of the company's two Knoxville, Tenn. plants will supply demand for electrolytic manganese in stainless and mild steels.

Six thousand pounds of a polyphenyl ether will be supplied by Monsanto to the Air Force under a contract recently awarded. The fluid is one of a group developed by the company last year and announced by the Air Force as a major advance in fluids research. It remains liquid and retains its lubricating ability at temperatures up to 900°F, while high temperature lubricants now in use have a limit of about 500°F. The fluid will be evaluated for use in future hypersonic aircraft.

New hydrogen treating system placed on stream by United Refining at Warren, Pa., refinery, is designed to upgrade virgin naphtha used as feed stock for reforming into high octane gasoline. The Unifining system, designed by Blaw-Knox, is applicable to a wide range of petroleum products. It consists of stripping tower, horizontal flash drum and heat exchanger train, vertical heater and reactor.

Operation of four major AEC facilities by Union Carbide will continue under an extension of an existing contract until 1964. Under the cost-plus-fixed-fee contract Union Carbide Nuclear Co. operates two large production plants and a research and development laboratory in Oak Ridge, Tennessee, and the gaseous diffusion plant at Paducah, Kentucky.

Construction of a $¾ million contact sulfuric acid plant at Cairo, Ohio, will be undertaken by American Agricultural Chemical. The plant will use elemental sulfur as a raw material, and will use Monsanto Chemical Co. vanadium sulfuric acid catalyst.

For more information, circle No. 38

ECO ENGINEERING NEWS

the big name in small pumps for the process industries

VOL. 1, NO. 4

Pumping Notes

•

World-Wide Demand

ECO pumps are being sold in 47 different countries, outside of the "Iron Curtain."

Interesting examples are 316 Stainless Steel ECO GEARCHEM® Pumps with TEFLON† trim for handling ethylene dichloride and nitroglycerine, ordered by Nitroglycerine Aktiebolaget, Gyttorp, Sweden—the business founded by Alfred Nobel of the world famous Nobel Peace Award.

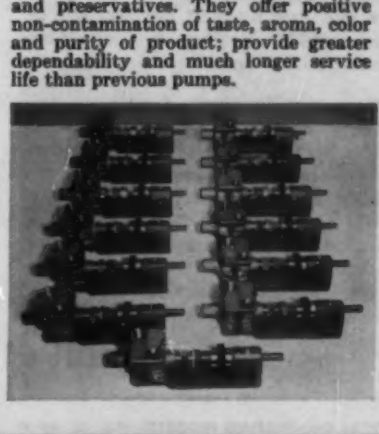
Also—a recent order for 14 ECO ALL-CHEM® Carpenter-20 Stainless Pumps from India, for Atomic Energy applications.

And another application of ALL-CHEM Pumps by Aktiebolaget Bofors of the 2nd World War Bofors Gun fame.

ECO Export Sales are under the direction of Mr. Joseph Rizzo, Empire State Building, New York, N.Y., U.S.A.

ECO Midgets Serve Green Giant

Thirteen ECO ALL-CHEM 316-Stainless Steel Pumps with Neoprene impellers, carbon bearings and chemically impervious TEFLON Packings are helping to pack Green Giant Corn, Peas and other delectable vegetables at Le Sueur, Minnesota. These little pumps handle seasoning and preservatives. They offer positive non-contamination of taste, aroma, color and purity of product; provide greater dependability and much longer service life than previous pumps.



New GEAR-VAC Valve*

This new engineering development of ECO Engineering Company is expressly designed to energize flows of highly viscous (up to 250,000 SSU) media and to dispense them with positive metering accuracy in volumes up to 2 gpm. To accomplish this, the GEAR-VAC Valve produces almost absolute vacuum, causing the viscous mass to collapse into the vacuum pocket, providing a constant supply in the gear chamber for positive dispensing with reproducible metering accuracy within ± 2 percent.

Revolutionary Advantages

The ECO GEAR-VAC Valve offers a novel and distinct contribution to process equipment technology.

It eliminates the need for heating such viscous media before passing through the valve as is the case with cumbersome plug valves. It also eliminates sluggish and time-consuming gravity feed of such media.

Linear, Bubble-Free Flows

Flows are linear, bubble-free and can be accurately varied at will—as contrasted with the performance of plug valves which, when used to control flow, yield greatly reduced, lumpy and spasmodic flows. ECO GEAR-VAC Valves, instead of restricting passage of media, develop reduced flows by correspondingly reducing the RPM of the gear mechanism. Also, when used to dispense highly viscous, adhesive or cohesive media, there is no leakage past the gear train. Hence it performs like any plug, check or shut-off valve in positively stopping flow of media.

Manual or Motor Operated

ECO GEAR-VAC Valves are offered with handwheel for manual operation (where the amount dispensed may be determined by the handwheel travel), and motor-operated with pulley, sprocket wheel or flexible shaft drive, for remote or process-controlled operation on constant or cyclic flows.

Simplicity of Design

This unit represents features of design which offer rapid and complete accessibility to bearings and gear train. It regularly features standard 150 lb. ASME 3 in. flange on suction side for connection to tank, reactor, etc. Tapered conical suction port design offers minimum resistance to sluggish media. Threaded discharge port is ¾".

*Trademark applied for †duPont Trademark

industrial news

An expansion of terephthalic acid, ethylene glycol and ethylene oxide production is being completed by Mitsui Petrochemical Industries, Ltd., at Iwakuni City, Japan. Mitsui's terephthalic acid plant, which uses Amoco Chemicals xylene oxidation process, has doubled its production capacity to about 30 million pounds a year. The product is ultimately converted to Terylene polyester fiber in Japan under Imperial Chemical Industries licenses. Also doubled in capacity is the ethylene glycol plant, while the ethylene oxide plant is being expanded to about 26 million pounds a year capacity.

Two new major scientific divisions, High Energy Physics and Solid State Science, have been established by The Argonne National Laboratory. The High Energy Physics Division, in order to investigate the properties of unstable particles from which matter is made, has begun construction on a 12.5 billion electron volt particle accelerator, the Zero Gradient Proton Synchrotron (ZGS). Solid State Science Division work includes the development of materials which can withstand conditions of temperature, pressure, and radiation exposure that now seem prohibitive. The new two divisions make a total of 17 at Argonne where studies are conducted on the peaceful applications of atomic energy.

Enlargement by 50 percent of the sodium chlorate plant of American Potash & Chemical at Aberdeen, Miss. will bring capacity up to 22,500 tons per year when completed in late 1960. The project was brought about by increased consumption by the pulp and paper industry.

Uranium Reduction Company has authorized a \$2 million expansion of its Moab, Utah, plant. Under a recently negotiated AEC contract, one of the existing acid circuits will be converted to a carbonate leaching circuit utilizing autoclaves.

A multi-million pound ester plant is being added to Colton Chemical's (Air Reduction) installation at Elkton, Md. The 20% boost in capacity has been made necessary as a result of widening use of polyvinyl acetate and copolymer resin emulsions in paint, paper and adhesive industries. The new plant will manufacture dibutyl maleate, dibutyl phthalate, and other products used in emulsion systems.

For more information, turn to Data Service card, circle No. 74

A.I.Ch.E. candidates

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions. These names are listed in accordance with Article III, Section 8 of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Members and Associate Members will receive careful consideration if received before October 15, 1959, at the office of the Secretary, A.I.Ch.E., 25 West 45th Street, New York 36, N. Y.

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Dunbar, Barrie, *West Columbia, S. C.*
Dutton, Dennis T., *Chester, Pa.*

Epifano, Robert, *West Long Branch, N. J.*
Ericson, Dale R., *Junction City, Wisc.*

Fajans, Robert G., *Yorktown, Va.*
Feren, Conrad J., *Chicago, Ill.*
Ferris, Robert R., *New Martinsville, W. Va.*
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Flickinger, Charles W., Jr., *Verona, Pa.*
Ford, Fred Eddy, *Murphysboro, Ill.*
Foster, Jerry, R. *Charleston, W. Va.*
Francen, Vernon L., *St. Paul, Minn.*
Frick, Douglas G., *Ogdensburg, N. Y.*

Gall, Robert L., *Detroit, Mich.*
Garrett, Arthur S., *Drexel Hill, Pa.*
Geise, Robert H., *Cheektowaga, N. Y.*
George, James W., *Allentown, Pa.*
Gilbert, Richard E., *Lincoln, Neb.*
Glannon, E. Mark, *Allison Park, Pa.*
Goff, David, *Pittsburgh, Pa.*
Gold, Steven J., *Newark, N. J.*
Greene, Howard L., *Binghamton, N. Y.*
Greiner, Burton E., *Elizabeth, N. J.*
Griffith, Richard M., *Stamford, Conn.*
Gross, George D., *Pittsburgh, Pa.*
Gross, William S., *Springfield, Mass.*

Hages, George, *Aliquippa, Pa.*
Haines, Richard C., *Wilmington, Del.*
Haney, Ronald R., *Greensburg, Pa.*
Hanson, Norman P., *Portland, Ore.*
Harkins, Alvin E., Jr., *Texas City, Texas*
Hawk, Charles A., *Racine, Wisc.*
Hendricks, Patrick T., *Louisville, Ky.*
Hensley, Jerry M., *Longview, Texas*
Hessel, James, *Cleveland, Ohio*
High, Orval J., *Wyandotte, Mich.*
Hinson, Kenneth E. *Marietta, S. C.*
Hoffecker, Robert B., *Ponca City, Okla.*
Hoffman, Terrence W., *Hamilton, Ont., Can.*
Hollmer, Alvin, *Schuylerville, N. Y.*
Holohan, John F., Jr., *Pittsburgh, Pa.*
Hougland, John W., *Lima, Ohio*
Humphreys, Kenneth K., *Chicago, Ill.*
Hundley, Melvin A., *Shippingport, Pa.*

Jakubik, Robert F., *Cleveland, Ohio*
Jamison, Harry W., Jr., *Nyack, N. Y*
Jentzen, Carl A., *North Haven, Conn.*
Johnson, William C., *St. Paul, Minn.*
Johnston, Tom R., *Kingston, Ont., Can.*
Jones, Roy E., *Boulder, Colo.*
Junghans, Philip R., *Brooklyn, N. Y.*

Kamm, Gerard, *S. Charleston, W. Va.*
Kaufer, Daniel M., *Albion, Pa.*
Keddie, William J., *Tarrytown, N. Y.*
Kennedy, James C., *Tuscola, Ill.*
Kinard, Glenn E., *Red Lion, Pa.*
King, William R., *Oil City, Pa.*
Kinney, John F., *Louisville, Ky.*
Kitto, Clyde W., *Fayetteville, N. Y.*
Klusnick, Joseph Vernon, *Detroit, Mich.*
Koltun, Stanley P., *Metairie, La.*
Kostic, Robert B., *Gulfbreeze, Fla.*
Kowalick, James F., *Philadelphia, Pa.*
Kuebler, Richard J., *Sidney, N. Y.*
Kunesh, John G., *South Euclid, Ohio*
Kung, E. Y., *Pittsburgh, Pa.*

Lawyer, James D., *Choctaw, Okla.*
Lederle, George M., *Westfield, N. J.*
Lieb, Dean E., *Carlisle, Pa.*
Liebreich, Joseph A., *King of Prussia, Pa.*
Livingston, Richard J., *Topeka, Kans.*
Logan, F. Eugene, *Indian Head, Md.*
Love, Frank, *Memphis, Tenn.*
Luzar, Ronald V., *Bound Brook, N. J.*
Lynn, LeRoy L., *Pittsburgh, Pa.*

Mandros, Platon Nick, *Charleston, W. Va.*
Maxwell, Russell, Jr., *Pittsburgh, Pa.*
Mayo, Richard E., *Hampton, Va.*

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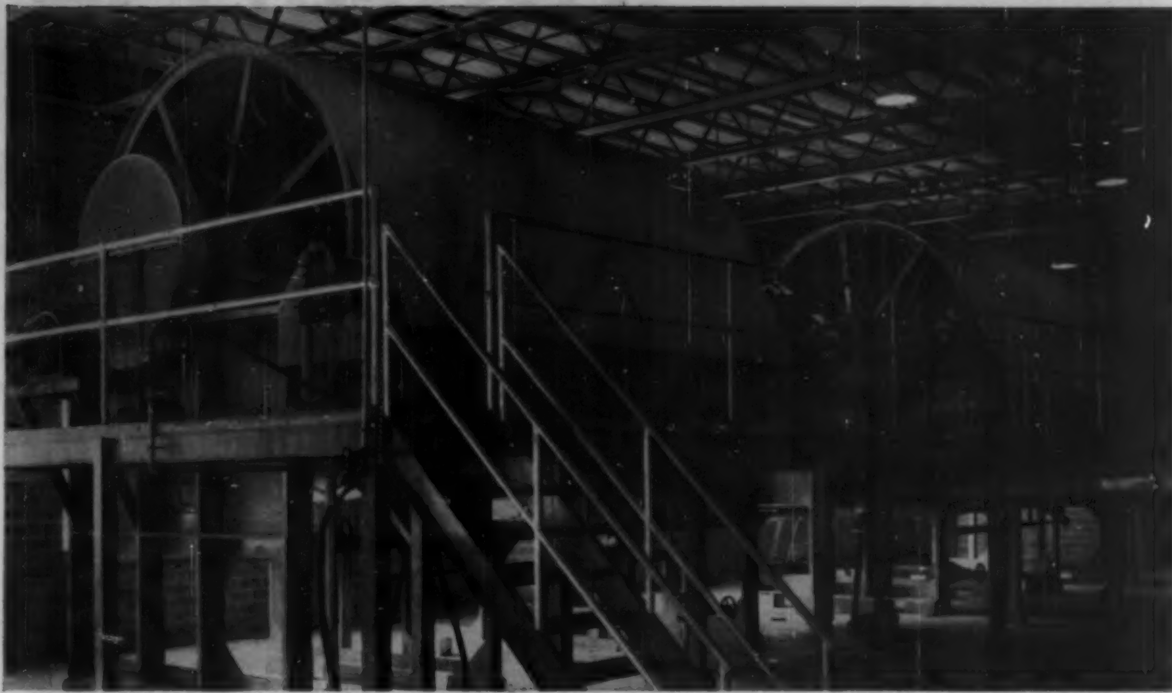


FEinc Rotary Vacuum String Discharge Filters at The Hubinger Company, Keokuk, Iowa.

FOR THE HUBINGER COMPANY . . .

STRING DISCHARGE FILTERS *solved the problem*

These FEinc rotary vacuum filters were recently custom built to specifications for The Hubinger Company, Keokuk, Iowa. The job they're doing is a tough one . . . filtering gluten derived from the wet milling of corn.

The string discharge design was selected as the only workable method for cleanly removing the thin, high-protein gluten cake which causes scraper filters to bog down. Each unit has over 500 square feet of filter area.

LOW MOISTURE CAKE CONTENT

Operating continuously, these string discharge filters eliminate blow-back and produce a cake of low moisture content. Stainless steel construction helps maintain product purity according to standards established in over 75 years of starch production.

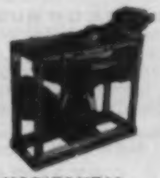
The FEinc filters in this installation are examples of how custom-made units provide solutions to many difficult continuous filtration problems in the chemical processing industry.

For help with your problem, see our insert in Chemical Engineering Catalog or write today, Dept. CEPF -959, for free bulletins and technical advice. Simply state your basic requirements.

For a Bigger Yield

FE INC.

STRING



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A.I.Ch.E. candidates

from page 142

McClurg, Charles F., *Yardley, Pa.*
McDaniel, William N., *Dallas, Texas*
McElmurry, Barry R., *Richmond, Calif.*
McKellar, George W., *Columbus, Miss.*
McKneely, Roy S., *Lake Jackson, Texas*
Michaels, George E., *Pittsburgh, Pa.*
Millington, Richard B., *Los Angeles, Calif.*
Montagnino, J. C., *Hicksville, N. Y.*
Moran, Frank Robert, *Belle Vernon, Pa.*
Morton, E. Lawrence, Jr., *Baton Rouge, La.*
Moser, Oscar, Jr., *Midland, Texas*
Moyer, Richard N., *Kenmore, N. Y.*

Nardacci, Joseph L., *Albany, N. Y.*
Nason, Raymond W., Jr., *Pittsburgh, Pa.*
Neddermeyer, Norman K., *Lakewood, Ohio*
Neidhart, John F., *Trenton, Mich.*

O'Neil, J. Roger, *Susquehanna, Pa.*
Opp, David A., *Vestal, N. Y.*
Orr, Lawrence E., *Ogden, Utah*
Oubre, Ronald J., *St. Martinville, La.*

Padfield, Don, *Houston, Texas*
Patsias, Terry, *Detroit, Mich.*
Pauls, Allen C., *Dayton, Ohio*
Peck, W. Perry, *Buffalo, N. Y.*
Petrie, Peter J., *Great Neck, N. Y.*
Pickard, William E., *Waltham, Mass.*
Pierce, John Gerald, *Winter Haven, Fla.*
Piontek, Walter S., *Lackawanna, N. Y.*
Poesik, Steve R., *Boulder, Colo.*
Porter, J. L., *Toronto, Ont., Can.*
Powell, Kenneth E., *Corpus Christi, Texas*
Powers, William E., Jr., *Pittsburgh, Pa.*
Pray, Larry A., *El Dorado Springs, Mo.*

Quigley, John Joseph, *Griffith, Ind.*

Randall, John C., *Hendersonville, N. C.*
Rickwald, Ronald R., *San Diego, Calif.*
Risk, Marvin R., *East Cleveland, Ohio*
Ripps, David L., *New York, N. Y.*
Rodgers, Louis H., *Wareham, Mass.*
Roeder, Richard A., *Piggott, Ark.*
Roosen, John J., *Detroit, Mich.*
Rosenheimer, Michael Oscar, *Flushing, N. Y.*
Rossa, Leonard G., *Cleveland, Ohio*
Rumpf, Norman, *Tenafly, N. J.*
Ruppel, Thomas C., *Pittsburgh, Pa.*

Sheff, James R., *Richland, Wash.*
Shepherd, Richard E., *Bellaire, Texas*
Slattery, John C., *Evanston, Ill.*
Smith, George Newton, *Poplarville, Miss.*
Smythe, Dudley, Jr., *Belton, Mo.*
Sobyak, Francis J., *Bethlehem, Pa.*
Sole, James W. *Philadelphia, Pa.*
Soltis, John A., *Hyattsville, Md.*
Sparks, Harold L., *Nederland, Texas*
Stabel, Lawrence G., *F.P.O., New York, N. Y.*
Stavast, Wilbur, *Denver, Colo.*
Steinman, Joseph B., *F.P.O., San Francisco, Calif.*
Stuckey, A. Nelson, Jr., *Baton Rouge, La.*
Stump, Roger, *New Philadelphia, Ohio*
Sturtevant, Robert L., *Wellesley, Mass.*
Sullivan, Gerald A., *Detroit, Mich.*

Tarring, Henry W., II, *Havre de Grace, Md.*
Taylor, Byron N., *Charleston, W. Va.*
Thompson, John W., *Webster Groves, Mo.*
Topham, Gordon A., *Shawinigan, Que., Can.*
Turek, Allen C., *Cleveland, Ohio*

Van Alstyne, Hugh M., *Valleyfield, Que., Can.*
Van Horn, David J., *Philadelphia, Pa.*
Vetter, Frank W., *Baton Rouge, La.*

Walitt, Arthur, *Little Neck, N. Y.*
Wallace, Richard A., *Brooklyn, N. Y.*
Weigel, Thomas, *F.P.O., San Francisco, Calif.*
Weiss, William J., *Savannah, Ga.*
Weissman, Barry Jay, *Brooklyn, N. Y.*
Wilson, Donald E., *Cincinnati, Ohio*
Wrench, Richard E., *Port Arthur, Texas*
Wyatt, Jack L., *Texas City, Texas*

AFFILIATES

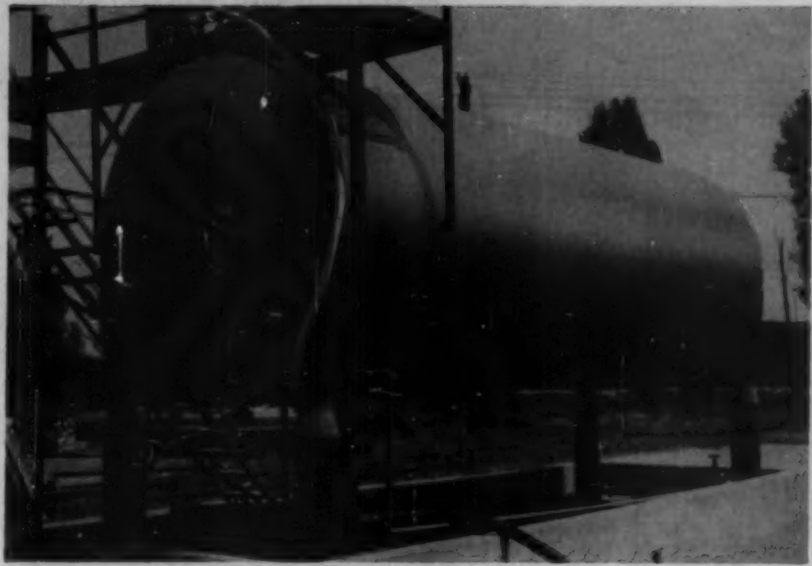
Seaton, Ralph E., *Allen Park, Mich.*

Varcum Chemical has been purchased by Reichhold Chemicals. The Niagara Falls company manufactures liquid, powdered and solid phenol formaldehyde resins, as well as resins for can coatings, paints, and varnishes. This acquisition, which gives Reichold its new line of resins and compounds, will be operated as a division of RCI.

Continuing Reichhold's expansion in the synthetic resin field, a new one-half million dollar formaldehyde plant has gone on stream in Kansas City, Kansas. Capacity of the new facility, the company's seventh domestic formaldehyde plant, is 30 million pounds per year. The chemical will be used in the manufacture of synthetic resins for plastics, adhesives and surface coatings.

A nitric acid producing unit is planned by Cyanamid of Canada (American Cyanamid). Said to be Canada's largest single unit, it will have a capacity of 190 tons daily, and will be used to augment Cyanamid's existing nitric acid production at Welland, near Niagara Falls, Ontario. Ammonia used in manufacture will be supplied by a plant expansion at the Welland site.

FLUIDICS* AT WORK



Heat transfer through Glasteel higher than most suspect

A recent article in *Chemical Engineering* by Edward J. Ackley, Pfaudler applications engineer, demonstrates an important fact: *you lose little or no heat transfer efficiency when you use Glasteel for service with viscous, corrosive or dirty fluids.*

Mr. Ackley's findings show that, under many process conditions, *over-all* coefficients of heat transfer for Glasteel are comparable to those of materials having much higher thermal conductivities.

For example, when cooling an organic liquid the service heat transfer coefficient for a Glasteel reactor is 91.3% of that for a stainless steel vessel. If the liquid is viscous, the coefficients for the two are *almost identical.*

If you missed the article, request Reprint No. 531.

For additional information, write our Pfaudler Division, Dept. CEP-99, Rochester 3, N. Y.

Pfaudler Permutit is a world-wide company with manufacturing plants in:
Germany: Pfaudler-Werke A.G.
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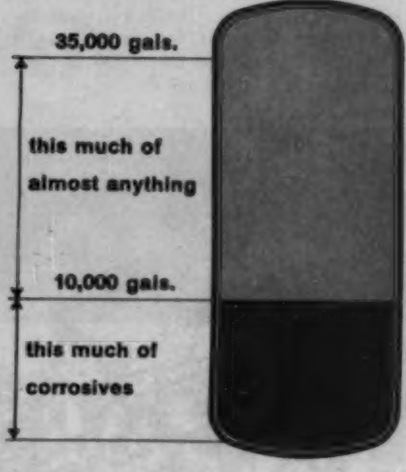
Mexico: Arteacero-Pfaudler, S.A.
Japan: Shinko-Pfaudler Co., Ltd.
as well as *four* plants in the U. S. A.

It costs less with Chemstor when you store . . .



Chemstor Glasteel Tanks actually cost less than stainless steel when you work with volumes between ten and thirty-five thousand gallons. These are savings you can pocket today.

It takes a little longer for the savings to show when you're storing less than ten thousand gallons. But the savings are still impressive, especially when you store corrosives. Savings show up in longer service life because of the almost universal corrosion resistance of Glasteel. Resists all acids (except HF) and mild alkalies.

And in all sizes you have full advantage of Glasteel's ease of cleaning and ability to protect product purity and flavor.

Vertical and horizontal designs supplied from 500 to 35,000 gallons' capacity.

A new specification sheet makes it easier for you to order Chemstor Tanks. You can quickly get one of these sheets from your Pfaudler representative. Write in your capacity needs, openings, valving, etc.

The two- and five-thousand gallon sizes are stocked for 10-day delivery.

A new bulletin on Chemstor Tanks is now available.

*FLUIDICS is a new Pfaudler Permutit program that provides a modern, imaginative approach for handling and processing liquids and gases more profitably.

PFAUDLER PERMUTIT INC.

Specialists in FLUIDICS . . . the science of fluid processes

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RICHARD G. NEWHALL, *Associate Editor*
ACS Applied Publications

San Francisco—Engineers gather in December

San Francisco is a city of hills. It is a city of views, of cable cars, of sophistication. It is the financial capital of the west. But it is also a state of mind. When you come to San Francisco for the A.I.Ch.E. Annual Meeting December 6-9, you will want to take some time out to find what it has to offer.

San Francisco is a compact city of about 45 square miles and some 800,000 inhabitants located in the hills between the Bay and the Pacific Ocean at the end of the long Peninsula. From meeting headquarters at the Sheraton-Palace Hotel, it is a few blocks to Union Square—the heart of the city's fashionable shopping area, and the starting point for cable car excursions over Nob and Russian Hills to Fisherman's Wharf. The Wharf is both the home port of a fleet of commercial fishing boats and a delight to the sea food lover.

Coit Tower, the Top of the Mark, Twin Peaks, or a vantage point on one of the many San Francisco hills will give you breathtaking vistas of the ocean, the Bay, the white city gleaming in the sun, or of bridges flung across improbable stretches of water.

The city is noted for its foreign quarters. A walk along lower Grant Avenue will take you through one of the largest Chinese cities outside mainland China. There you can experience the sights, sounds, and smells of the Orient, and there you can eat authentic Chinese meals.

An excursion to North Beach at the upper end of Chinatown will take you to the Italian section. You can stand in Washington square in the heart of North Beach and participate vicariously in an Italian wedding in the impressive Church of Sts. Peter and Paul across the way. You can visit the Italian restaurants for scallopini alla marinara, cannelloni, pizza, cappellini, or spaghetti. You can drop in at that unique establishment, the Bocce Ball Court, where singers entertain in the bar with arias from the Italian operas while a game of bocce ball—a frenetic Italian version of lawn bowling—goes on in the rear.

In several restaurants in the city, behind an unprepossessing facade, you can find the delicate and exotic atmosphere of Japan. There you will sit on a matting floor before low tables

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From Golden Gate Bridge (upper left) to the Oakland Bridge (lower right) the heart of San Francisco has something to offer every taste and interest.

San Francisco preview

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(after courteously removing your shoes at the door) and sip hot saki while a doll-like Japanese waitress in a flowering kimono ceremoneously prepares authentic sukiyaki in front of you.

San Francisco is one of the world's truly great cities for the gourmet. San Franciscans know good food; they love to dine out. No matter what your favorite dish, you are almost sure to find it somewhere in one of the city's restaurants.

For the more intellectually inclined, you can turn to the museums, aquariums, and art galleries set among the lawns, trees, and flowers of Golden Gate Park. Or, visit the art exhibits at the California Palace of the Legion of Honor on a hill overlooking the Pacific. Closer to downtown there is the city's stately Opera house with its opera, ballet, and symphony concerts.

After hours of listening to technical papers you may wish to relax along

At the edge of fabulous Chinatown, the famous cable cars begin the climb up renowned Nob Hill.

the night life trail. Outstanding jazz combos in smoky, dimly lighted nightclubs—smooth dance bands in luxurious ballrooms—singers of folk music and tellers of sick, sick jokes in basement hideaways—San Francisco has them all.

But San Francisco is more than all of these things. It is also the financial capital of the West and the heart of a great industrial complex that surrounds the Bay. And much of this industry is chemical.

Some of the largest companies in the U. S. have their headquarters or at least important divisions in the

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Union Square, the heart of San Francisco's downtown shopping district.

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area. Giant Standard Oil Company of California has its main office in the city. Its largest refinery, its main research laboratories, and much of its petrochemical processing facilities are across the Bay in Richmond.

Dow has major plants and research facilities some 40 miles away at Pittsburg. Important production units of Stauffer and much of its research activities are in the Bay Area. Shell Development's main laboratories are just beyond the eastern end of the Bay Bridge.

In other parts of the Bay Area, we find Food Machinery and Chemical, General Electric's Atomic Power Equipment Division, Kaiser Aluminum and Chemical, and others. They range in size from the industrial giants employing hundreds of chemists and chemical engineers to the one-man plant reclaiming TV tube components by dissolving the glass in hot caustic under pressure.

Program

Feeding ideas, technical personnel, and developments into this industry are the educational institutions of the Bay Region. More than half a dozen colleges and universities can be found within 50 miles of San Francisco. The University of California, has its main campus just across the Bay within view of San Francisco. Another center of science and engineering is Stanford University and its affiliate, Stanford Research Institute, some 35 miles to the south.

The meeting itself has a technical program that promises to be one of the best of the year. One of the features of the gathering is a symposium

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San Francisco preview

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on *Quality Criteria for Catalytic Cracking Stocks and Methods of Preparation.* The 12-paper symposium, tentatively scheduled as an all-day session, is headed by Wheaton W. Kraft. Another all-day meeting will be *Process Development by Statistical Methods*, G. E. P. Box and J. S. Hunter. *Process Dynamics*, E. E. Johnson, and *Operations Research*, R. R. Hughes, also promises to be of special interest. Among other topics to be taken up: *Fundamental Aspects of Chemical Engineering in the Pulp and Paper Industry*, J. L. McCarthy; and *Selected Heat Transfer Papers*, J. G. Knudson.

A real high spot will be another major roundtable, no-holds-barred, discussion session on *Safety in Air and Ammonia Plants*. It will be held in four full sessions on two days.

Complete details on the program of the meeting will appear in next month's CEP.

Construction has started on a 50 million pound a year caprolactam manufacturing unit at Du Pont's Beaumont, Texas, plant. The Beaumont plant will produce caprolactam by a new process which uses low-cost petroleum derivatives. Cyclo-hexylamine, a co-product, will also be produced.

A 66 million cubic feet per day gas processing plant near Carstairs, Canada, will recover approximately 115,000 gallons of liquid hydrocarbons per day, according to plans. The $3½ million grass roots installation will be built under a contract awarded to Fluor by the Carstairs Operators' Committee. Completion is scheduled for early 1960.

Candidates for A.I.Ch.E. National Office—Correction

The biography of J. J. Healy, candidate for vice-president in 1960, on page 114 of the August issue, contains the sentence, "In his present position on Monsanto's Corporate Planning Group, he is responsible to the president for all phases of long range planning for the company." This could imply that Mr. Healy is solely responsible for long range planning. This is not correct. It is the entire four-man Corporate Planning Group, of which Mr. Healy is a member, that bears this responsibility.

Institute lecturer, Colburn Award, winners named

Thomas H. Chilton has been selected as Institute Lecturer for 1959. He has chosen *Nitric Acid by Ammonia Oxidation* as a topic for his lecture and monograph at the forthcoming Annual Meeting in San Francisco in December.

Nationally known in the academic world and in professional engineering circles, the former Du Pont executive is particularly noted for his work on fluid flow, heat transfer, distillation and absorption.

His career with Du Pont dates back to 1925, when he started with the company as a chemist at the experimental station. He later became director of the technical division heading the chemical engineering and metallurgical research groups. Chilton took over the post of technical adviser to the Engineering Department early in 1958.

He recently retired from his position at Du Pont in order to undertake a series of teaching assignments. The first of these begins in September, as Regents' Professor in chemical engineering at the University of California for the coming academic year.

This type of work is not new to the educator-scientist. He gave extension lectures in the Department of Chemical Engineering at Columbia University from 1937 to 1941, and since 1953 has served on the advisory council of the Chemical Engineering Department at Princeton.

Until recently, Chilton was a member of the board of editors of ACS monographs, and served as section editor of *Chemical Abstracts* for Industrial Chemistry. A member of the advisory board for books in chemical engineering for a leading publishing house, he also served for several years as a member of the advisory committee on grants of the Research Corporation.

A past president of A.I.Ch.E., he is one of only five men to receive the Founders' Award to date. Chilton has served on many committees, and has held positions in the local section as well as the top national position. His many other activities include the post of president of the Engineers' Joint Council.

The many honors Chilton has received include the Chandler Medal,

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the University Medal from Columbia, the Egleston Medal from the Engineering School Alumni Association. The president's Certificate of Merit was given to him in 1948 for services to the National Defense Research Committee during World War II in the field of production and use of oxygen.

Chilton is the eleventh Institute Lecturer. The Institute Lecture inaugurated in 1946, provides that each year one person is invited to present a comprehensive review of chemical engineering science in his field of specialization.

Sheldon K. Friedlander has been presented with the Allan P. Colburn Award for his outstanding contribution to chemical engineering literature. Friedlander was cited for his research paper, published in the *A.I.Ch.E. Journal*, entitled "Mass and Heat Transfer to Single Spheres and Cylinders at Low Reynolds Numbers".

The Allan P. Colburn Award (formerly the Junior Award) is presented annually to encourage excellence in contributions to the publications of the Institute, and is limited to persons who have not passed their 35th birthday. It is named after the late Allan Philip Colburn, one of the leading chemical engineers in A.I.Ch.E., and provost of the University of Delaware until his death in 1955.

Friedlander, a member of the faculty of Johns Hopkins University, is currently serving as acting chairman of the Department of Chemical Engineering. He came to the university in 1957, after serving at Columbia for three years. Previously, he has done research at the University of Illinois, the Knolls Atomic Power Laboratory, Harvard School of Public Health, and the Socony Vacuum Research and Development Laboratory. He is also consultant to the Atlantic Research Corporation. Friedlander's current research projects are being conducted

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with the assistance of grants from the Atomic Energy Commission, the National Science Foundation and the Public Health Service.

The 31 year old educator has written widely for professional journals in the chemical engineering field.

Presentation of the award, which consists of a certificate and a plaque, will be made at the Annual Meeting of the Institute in San Francisco in December.

Ray P. Dinsmore was recently honored by directors of Goodyear for his contributions to the rubber industry when he was presented by the board of directors with a 45-year service emblem. Dinsmore, vice president of research and development, observed his 45th year with the firm in July.

His career in research has been highlighted by the Colwyn Gold Medal for 1947, awarded by the Institution of the Rubber Industry for his work in synthetic rubber, including research, development and application. He also received the Charles Goodyear Medal for 1955 from ACS Rubber Division.

As assistant deputy rubber director for the US during World War II, Dinsmore organized and directed research and development work on synthetic rubber for the government, and coordinated activities of both industrial and university laboratories.

Graduated from MIT in 1914, Dinsmore joined Goodyear's experimental

Ray Dinsmore (center) receives his 45-year service pin from Goodyear board chairman E. J. Thomas (left) and Goodyear president R. DeYoung.

Department in Akron that same year. He has worked for the company as compounder, chief chemist at several of its plants, and became vice president in 1943. From the Goodyear research laboratories under his direction have come such industry milestones as the first rayon cord tire, the LifeGuard safety tube, low pressure

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Super-Cushion tire, oil extended synthetic rubber, rubber based paints, boilable vinylfilms and food packaging films. He directed the research that led to Pliofilm.

He is a director of A.I.Ch.E.

At Esso Standard Oil, **Clifton C. Garvin, Jr.** has been appointed assistant general manager, Supply Department. Garvin, who previously worked as operating superintendent, Baton Rouge refinery, will make his headquarters in New York City.

Philip W. Pritchett has joined the technical staff of the Esso Research Lab, Baton Rouge, La.

J. Q. Cope elected vice president, chemical products and processes at California Research. Cope, who has held a number of positions in Standard of California since 1931, was, in 1950, vice president and director, California Research and Development. This was the company formed to operate the Livermore, California, AEC project.

California Research, in other staff changes, appointed **John R. Milne** to the position of research engineer, producing research, at the company's La Habra laboratory.

E. H. Oliver, W. K. Roquemore, and **J. R. Lander** have been promoted at Humble Oil and Refining's Baytown, Texas, refinery. Oliver has been named general foreman, Process Division. Roquemore and Lander are assistant general foremen in the same division. In the Technical Division, **J. E. Lawson** is supervising engineer, also at Baytown, while **D. R. Moore** steps into the position of senior chemical engineer.

Edward G. Schwaegerle has been named manager, synthetic resin development, at Goodrich Chemical, Avon Lake, Ohio, Development Center. He joined the company in 1942 as junior chemical engineer, and has done considerable work in polymerization development.

Reno J. White moves into the post of assistant manager of the Fats & Oils Department at Blaw-Knox. White is with the Chemical Plants Division, Pittsburgh, Pa.

Paul H. Squires has been transferred to Du Pont's Washington Laboratory,

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Parkersburg, West Virginia, and advanced to supervisor. He is with the Research and Development Division, Polychemicals Department. In his new position, he will direct research on engineering services. Squires, since joining the company four years ago, has worked on theory and design of plastics processing equipment.

Curtis W. Clump is recipient of a $3000 grant to support research projects at Lehigh University. The grant is given by the committee on educational aid at Du Pont. Clump, a member of the chemical engineering faculty at the University, is engaged in nuclear engineering studies at Cornell University and at Brookhaven Atomic Energy Commission lab, Long Island, New York.

Edward F. Hensley has joined the operations Department, Dow Chemical International. He is manager of foreign engineering and construction projects. Hensley recently returned from an assignment in Japan where he assisted Asahi-Dow, Ltd. in engineering on a styron expansion project.

Peter D. Shroff joined Narmco Resins and Coatings in the newly formed post of manager, product engineering. His department also takes in the technical service section. Shroff, who comes to the company from Fluor, has also worked for GE.

Wilson C. Rich, Jr. named chief process engineer at J. G. White Engineering. He will head the company's process division.

William C. Knopf appointed technical director, USI Technical Center (US Industries). Prior to this, he was assistant director of research at International Minerals and Chemical for five years. Knopf also has taught in the field of physics and electrical engineering, and was assistant dean of the Technical Institute at Northwestern University. He is a member of the Nuclear Engineering Division of A.I.Ch.E.

Martin L. Kasbohm has transferred to the Tonawanda Laboratories, Linde (Union Carbide), and is assistant manager, Engineering Lab. He was previously with the Speedway Engineering Lab. Addition to the Tonawanda Lab is **Harrison B. Rhodes**, Drying and Purification Section, Molecular Sieve Products.

J. C. Mohan has been assigned to the American Viscose Fredericksburg, Va., Film Division plant as research and development representative.

R. Wayne Houston spent the summer at Brookhaven National Laboratory as visiting associate chemical engineer in the Nuclear Engineering Department. He is in charge of the program in nuclear engineering, Chemical Engineering Department, at the University of Pennsylvania.

A. G. Fennimore has been named manager, American Cyanamid's Willow Island, West Virginia, plant. Fennimore has held supervisory positions with American Cyanamid since he joined the company in 1940.

Matthew A. Killinen moves into the position of assistant general superintendent of the Painesville, Ohio, plant of Diamond Alkali. Killinen's service with Diamond dates back to 1930, when he joined the firm as head of the Magnesium Chloride Department.

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Hugh E. Toczek becomes purchasing supervisor, Major Subcontracting Department at North American Aviation. He is with the Los Angeles division of the company.

R. I. Stirton has been named general manager of the newly created Commercial Development Department at Oronite Chemical (Standard Oil of California). Other appointments include **R. E. Echols**, supervisor, market development.

Louis B. Perillo has joined the Thompson - Ramo - Wooldridge Products Company as manager, Contracts and Proposals Department. **Richard M. Hexter** has been named eastern regional sales manager of the company. His headquarters will be in New York City.

Philip H. Seaver has been appointed manager, engineering sales at Badger Manufacturing. Seaver, who has been a director of the company since 1957, will be in charge of sales activities in the Western Hemisphere. In other personnel changes, **Robert E. Siegfried** takes over as assistant engineering manager.

Kenneth W. Becker heads the Blaw-Knox Chemical Plants Division Chicago sales force as district manager. Prior to this, Becker was district engineer, sales, in the midwest territory for the company.

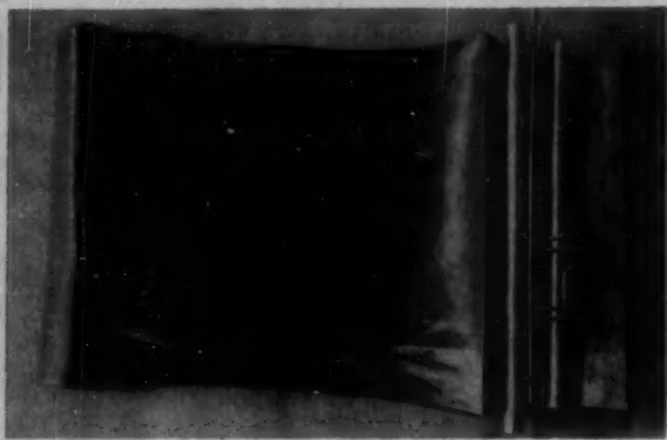
In top management reorganization at American Cyanamid, **R. T. Bogan** was named executive director. His responsibility is planning expansion into new markets outside the United States, for the overseas operating division.

Stanley J. Dumovich has been added to the staff of Air Reduction Chemical. He is located at the technical sales laboratory in Bound Brook, N.J.

A. C. Matthies will serve Enjay, New York petrochemicals marketing firm, on loan assignment in London until early 1960.

NECROLOGY

Ray Bonner Worthy, 68, former president of Mathieson Chemical, Industrial Chemicals Division, Va. After taking over this post in 1954, he later became consultant to Olin Mathieson Chemical Corp.



"Educator, inspiring teacher, vigorous leader, prominent engineer . . ." are the words under the name of George Granger Brown on this plaque recently dedicated to the memory of the former A.I.Ch.E. president at the U. of Michigan.

Esso Research's new Baton Rouge pilot plant for "aging" catalysts to determine their useful life.

A stream of ammonia molecules will generate a highly stable current in this tubular "heart" of Hughes Aircraft's new "atomic clock." The 30-lb. clock will neither gain nor lose one second in a thousand years.

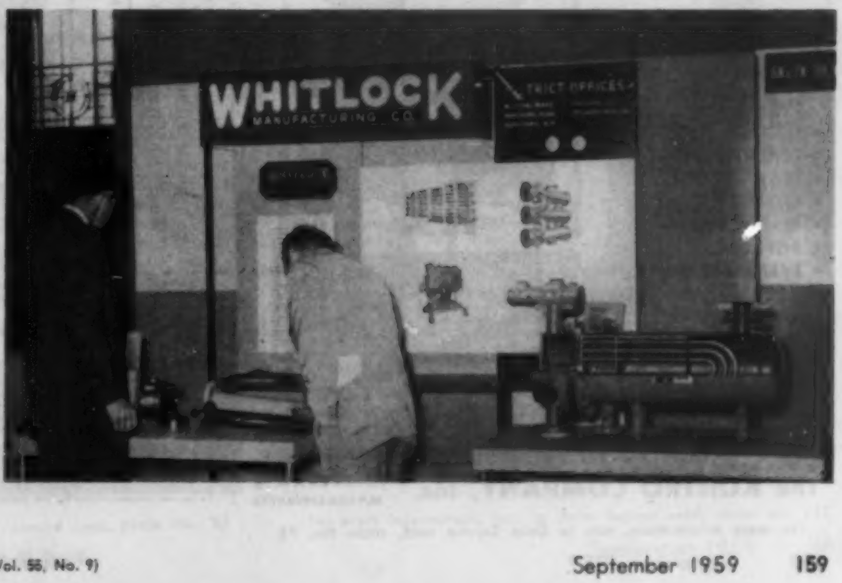
Myron Tribus (extreme left) of UCLA debating the merits of the spiral-type heat exchanger.

J. Conrad, A. Gudheim and L. J. Monty (l. to r.) with a model of Kontro's Adjust-O-Film.

Display of Monsanto's Aroclor heat transfer medium attracts a meeting participant.

A.I.Ch.E. president Don Katz makes the opening remarks to the banqueteers. Toastmaster, W. C. Beekley, president of Whitlock, Mfg. Co. is seated at his left.

Six hundred engineers at University of Connecticut for the jointly-sponsored A.S.M.E.-A.I.Ch.E. Heat Transfer Conference.



During a breather between sessions a couple of conferees pore over the innards of one of Whitlock's cut-away equipment models.

Rocket fuels, nuclear blasts, high temperature, at local sections

"Fertilizer in an ashcan" is the way one type of solid propellant rocket was described by B. R. Adelman at the **Southern California Section** *(R. D. Sheeline)* in May. The rocket referred to is an inexpensive aircraft Jato unit which uses ammonium nitrate-rubber combination as the propellant, and a low cost steel case. Adelman is vice president of United Research (United Aircraft), which is working on the development of solid propellant propulsion systems.

Solid propellant rockets consist of three main parts: propellant, case and igniter. They are very simple and therein lies their appeal. Compared to them, liquid fuels require tanks, pumps, turbines, gas generators, combustion chambers, plumbing, valves, fuel, liquid oxidizer, lube systems, controls, etc.

Approximate composition of typical composite propellants is:

Ammonium perchlorate (oxidizer)	75%
Elastomer (fuel)	23%
Miscellaneous	2%

It is apparent that this is a pretty heavily loaded elastomeric material. Nevertheless, for satisfactory performance, high tensile strengths, good elongation and ability to retain these properties at wide temperature extremes is desired.

The Atlas missile has a total weight of about 250,000 lbs. Unloaded, it weighs about 10 percent of that and is relatively easy to move around empty, with loading accomplished at the launching site. Hauling a loaded solid propellant of this weight created quite a problem, and held up this type of rocket development for some time. Now, Polaris, Minuteman, Sergeant and Pershing missiles are being satisfactorily handled.

A charge is usually designed so that a constant burning surface is maintained to provide gas pressure and thrust. Internal burning charges, such as the star perforated charge, have the advantage of insulating the case from the combustion products, permitting use of lightweight cases which do not lose strength from high temperature before burnout.

Present processing involves mixing raw materials in conventional sigma blade mixers, casting the mixed pro-

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SYMPOSIUM: Physical Properties of Liquids

Preprint 22—A Corresponding States Correlation for Higher Molecular Weight Substances *A. Bondi and D. J. Simkin, Shell Development Company, Emeryville, California*

Preprint 23—Liquid, Gas, and Dense Fluid Viscosity of Propane *K. E. Starling, B. E. Eakin, and R. T. Ellington, Institute of Gas Technology, Chicago, Illinois*

Preprint 24—The Viscosity of Liquid Mixtures *R. A. McAllister, Lamar State College of Technology, Beaumont, Texas*

Preprint 25—Reduced Thermal Conductivity Correlation for Ethylene: Its General Application to Gaseous Aliphatic Hydrocarbons and Their Derivatives *E. J. Owens and G. Thodos, Northwestern University, Evanston, Illinois*

Preprint 26—An Experimentally Verified Theoretical Study of the Falling Cylinder Viscometer *J. Lohrenz, G. W. Swift and F. Kurata, University of Kansas, Lawrence, Kansas*

SYMPOSIUM: Mixing

Preprint 27—Agitation of Non-Newtonian Fluids *A. B. Metzner, University of Delaware, Newark, Delaware, R. H. Feehs, E. I. du Pont de Nemours & Company, Inc., Penns Grove, New Jersey, H. Lopez-Ramos, Monterrey Institute of Technology, Monterrey, Mexico, R. E. Otto, Wright-Patterson Air Force Base, Dayton, Ohio, and J. D. Tuthill, Salem, New Jersey*

Preprint 28—Suspension of Slurries by Mechanical Mixers *J. Weisman, Nuclear Development Corporation of America, White Plains, New York and L. E. Efferding, Westinghouse Electric Corporation, Pittsburgh, Pennsylvania*

Preprint 29—Mass Transfer Coefficients for Solids Suspended in Agitated Liquids *J. J. Barker and R. E. Treybal, New York University, New York, New York*

SYMPOSIUM: Management of New Product Development

Preprint 31—What Management Does About New Product Development *L. A. Hatch, Minnesota Mining & Manufacturing Company, St. Paul, Minnesota*

Preprint 32—Who Develops New Products? *W. E. Kuhn, Texaco, Inc., New York, New York*

Preprint 33—When is the Development of A New Product Complete? *F. A. Soderberg, F. C. Huyck & Sons, Albany, New York*

Preprint 34—Developing New Products by Acquisition *L. B. Hitchcock, Lauren B. Hitchcock Associates, New York, New York*

Preprint 35—The Economics of Innovation *W. J. Riley, Food Machinery and Chemical Corporation, New York, New York*

SYMPOSIUM: Mixing Equipment

Preprint 40—Effectiveness of Mixing Tanks in Smoothing Cyclic Fluctuations *E. B. Gutoff, Ionics, Inc., Cambridge, Massachusetts*

Preprint 41—Small Bench Scale Stirred Reactors for Gas-Liquid Contacting *D. Hyman and J. M. Van den Bogaerde, American Cyanamid Company, Stamford, Connecticut*

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THIRD NATIONAL HEAT TRANSFER CONFERENCE

Following are the papers for the A.S.M.E.-A.I.Ch.E. sponsored Heat Transfer Conference at Storrs, Connecticut, from August 9-12, 1959.

101 **Fluid Mechanics and Heat Transfer in Falling Film Systems**
A. E. Dukler, Univ. of Houston, Houston, Texas

102 **Thermal Conductivity of Some Mesomorphic Compounds**
J. B. McCoy* and L. S. Kowalczyk, Univ. of Detroit, Detroit, Mich.

*Present address—Reichhold Chemicals, Inc., Detroit, Mich.

103 **Approximate Theory for Film Boiling on Vertical Surfaces**
Y. Y. Hsu and J. W. Westwater, Univ. of Illinois, Urbana, Ill.

104 **Heat Transfer in Saturated Boiling**
Yan-Po Chang and N. W. Snyder, Univ. of Notre Dame, South Bend, Indiana

105 **Populations of Active Sites in Nucleate Boiling Heat Transfer**
R. F. Gaertner and J. W. Westwater, Univ. of Illinois, Urbana, Ill.

106 **The Role of Surface Conditions in Nucleate Boiling**
Peter Griffith and J. D. Wallis*, Massachusetts Institute of Technology, Cambridge, Mass.

*Present address—The English Electric Co. Ltd., Whetstone, near Leicester, England

107 **Heat Transfer from Pre-mixed Gas Flames in a Cooled Tube**
D. W. Sundstron* and S. W. Churchill, Univ. of Michigan, Ann Arbor, Michigan

*Present address—The Linde Co., Indianapolis, Indiana

108 **The Effect of Electrolytic Gas Evolution on Heat Transfer**
F. O. Mixon*, W. Y. Chon and K. O. Beatty, Jr., North Carolina State College, Raleigh, N. C.

*Present address—E. I. du Pont de Nemours & Co., Wilmington, Del.

109 **Two-Phase Flow Rates and Pressure Drops in Parallel Tubes**
H. L. Foltz and R. G. Murray, Goodyear Atomic Corp., Portsmouth, Ohio

110 **A Theory of Local Boiling Burnout and its Application to Existing Data**
L. Bernath, E. I. du Pont de Nemours & Co., Wilmington, Del.

111 **Radiant Heat Transfer Through the Atmosphere**
Jin H. Chin* and S. W. Churchill, Univ. of Michigan, Ann Arbor, Michigan

*Present address—The General Electric Co., Cincinnati, Ohio

112 **Condensation on a Horizontal Rotating Disc**
K. O Beatty, Jr., North Carolina State College, Raleigh, N. C., S. S. Nandapurkar, Bombay State, India

113 **Condensation of a Vapor in the Presence of a Non-Condensing Gas**
W. W. Akers, J. E. Crawford* and S. H. Davis, Jr., The Rice Institute, Houston, Texas

*Present address—Magnolia Petroleum Co., Beaumont, Texas

114 **Condensation Inside a Horizontal Tube**
W. W. Akers and H. F. Rosson*, The Rice Institute, Houston, Texas

*Present address—Univ. of Kansas, Lawrence, Kansas

115 **Local Heat Transfer Coefficients and Pressure Drops for Refrigerant-22 Condensing in Horizontal Tubes**
M. Altman, General Electric Co., Philadelphia, Pa., R. H. Norris and F. W. Staub, General Electric Co., Schenectady, N. Y.

116 **A Large-Scale Plant Analysis of the Colburn and Hougen Analogy**
J. F. Revilock, National Carbon Co., Cleveland, Ohio, H. Z. Hurlburt, D. R. Brake, E. G. Lang, Consolidated Chemical Industries Division, Houston, Texas, and D. Q. Kern, D. Q. Kern Associated, Cleveland, Ohio

117 **Temperature Distributions in Solids with Electrical Heat Generation and Temperature Dependent Properties**
R. P. Stein and M. U. Gutstein, Columbia Univ., New York, N. Y.

118 **Determination of Core Dimensions of Cross-Flow Gas-to-Gas Heat Exchangers**
P. S. Lykoudis and R. M. Shastri, Purdue Univ., Lafayette, Indiana

119 **Heat Transfer Rates for Parallel Flow of Liquid Metals Through Tube Bundles**
O. E. Dwyer and P. S. Tu, Brookhaven National Laboratory, Upton, L. I., N. Y.

120 **Assessment of Heat Exchanger Data**
S. K. Jenssen, AB Rosenblads Patenter, Stockholm, Sweden

121 **True Temperature Difference of 1-2 Divided Flow Heat Exchanger**
D. L. Schindler* and H. T. Bates**, Univ. of Nebraska, Lincoln, Nebraska

*Present address—E. I. du Pont de Nemours & Co., Wilmington, Del.
**Present address—Kansas State College, Manhattan, Kansas

122 **Organization of Heat Exchanger Programs on Digital Computers**
J. J. Taborek, Phillips Petroleum Company, Bartlesville, Oklahoma

123 **Heat Transfer with Molecular Sieve Adsorbent: II. Heating with Longitudinal Finned Tubes**
B. D. Phillips, Linde Co., Tonawanda, N. Y.

124 **Heat Transfer with Molecular Sieve Adsorbent: I. Effective Thermal Conductivity**
B. D. Phillips, F. W. Leavitt and C. Y. Yoon, Linde Co., Tonawanda, N. Y.

125 **Heat Transfer in Baffled, Jacketed, Agitated Kettles**
Gary Brooks and Gouq-Jen Su, Univ. of Rochester, Rochester, N. Y.

126 **Heat Transfer to a Single Cooling Tube in a Moving Bed Reactor**
D. J. Loudin, National Lead Co. of Ohio, Cincinnati, Ohio, K. O. Beatty, Jr., North Carolina State College, Raleigh, N. C.

127 **Heat Transfer to Sodium-Potassium Alloy (NaK) in Pool Boiling**
Niels Madsen* and C. F. Bonilla**, Columbia Univ., New York, N. Y.

*Present address—Univ. of Rhode Island, Kingston, Rhode Island
**Present address—Puerto Rico Nuclear Center, Mayaguez, Puerto Rico

128 **The Thermal Conductivity of Several Plastics Measured by an Unsteady State Method**
W. M. Underwood and R. B. Taggart, Monsanto Chemical Co., Springfield, Mass.

Preprints of the above papers may be obtained from the American Institute of Chemical Engineers, 25 West 45th Street, New York 36, New York. They sell for 50¢ a piece. Members of the A.I.Ch.E. or A.S.M.E. Heat Transfer Divisions may purchase the entire set of 28 papers for $12.00.

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pellant into the rocket case, and curing at 100° to 180°F. For high performance, inert parts weight must be as low as possible. Steels with tensile strengths around 220,000 lb./sq.in. are used to achieve this.

Comparing liquid with solid propellants, one finds that liquids provide higher specific impulse, while solids have higher densities and require smaller cases to contain them. Burning times on solid propellant rockets are short, but getting longer; liquid rockets now have shorter burning times than previously. In short burning time, there is less drag and gravity loss, but the equipment is subjected to higher acceleration.

For ballistic missile applications, the pendulum has swung from the liquid V-2 philosophy popular after World War II, to the use of solid propellants. The operational readiness of solid propellant rockets was the over-riding factor in their selection for the Minuteman missile. Storable liquid propellants in rockets using burst diaphragms instead of valves may eventually provide real competition for solids.

George Bailey (r) chairman of the Chicago Section, and Karl Lady, Evanston Township High School Senior, discuss the chemical engineer in the plastics industry over a local television station. The highly successful series of seven programs, sponsored by the Section, explored what chemical engineers do in each of six industries.

Looking into the future, it appears that for the next ten years we will see solid propellants coming into their own in weapons, while for large projects, such as expeditions to the moon, satellites for weather forecasting or TV transmission, we will use liquids. Solid propellants may be used in very large booster units for these and other more ambitious missions where first stage rockets will achieve 20-30 million pounds of thrust, because they will be less expensive in large sizes.

Relatively small atomic bombs may be used to perform tasks that are expensive, or impossible by other means, Kenneth S. Pitzer told the May meeting of the **Northern California Section** *(William B. Hauserman)*. Operation plowshare, recently organized research program to develop peaceful uses of nuclear blasts, if not impeded by political controversy, may lead to even more rapid expansion in this field of modern technology. In the petroleum field, for example, he went on, underground distillation of crude oil from the huge deposits of oil shale may be achieved by setting off a small

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nuclear blast, cracking the rock formation and forcing the vaporized crude through it by pressure, and the residual high temperature area. One of the methods of cheaply distilling sea water, now under investigation, is by draining it into a hot cavity, formed by an underground blast, condensing the steam as usable fresh water as it percolates up through cooler strata. Extended a little further, the idea of using the steam to generate electric power is also possible. It has also been suggested that a small nuclear blast could be used to break up a hurricane. Of course the remaining questions of whether the residual radiation will constitute a major problem, the question as to the geophysics of such an underground blast, and the many practical engineering details, must all be worked out.

High temperature research

In the field of high temperature research, on new application of high temperature nuclear reactors, it has recently been found at the Los Alamos laboratories, that by using the vapor of some alkali metal as one leg of a thermocouple, voltages produced are considerably greater than any hitherto generated from devices converting heat directly into electrical energy. Results are eagerly awaited of current work to determine the amounts of carbon vapor that can be generated at temperatures of from 2500 to 4000°K, and the relative distribution of different molecular species composing it.

Fluidized solids techniques occupied the June meeting of the **Fairfield County Chemical Engineering Society** *(K. T. Kelly)*. Examples of commercial operations utilizing the technique were given by R. B. Thompson, Dorr-Oliver. Cited were the sulfide roasting for sulfuric acid industry, drying of solids, calcination, reduction of ores, and chlorination, with advantages and limitations of the fluidized approach.

The study course program of the **Charleston, West Virginia Section** *(G. E. Merryman)* was marked this season with a top enrollment of nearly 200 in the course on Economics of Chemical Company Operations. Also

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presented was a course on Commercial Law. The eight year old study course program is given each spring and fall in six bi-weekly sessions at a local college. It was so successful this year that the lecturers returned a total of $200 as contributions to the Section's college scholarship fund. Speakers for the course on Economics and topics were:

Chemical Business Finance, V. L. Andrews, Massachusetts Institute of Technology.

Market Research, J. I. Hughes, Manager, Marketing Analysis, Plastics Sales Division, E. I. duPont de Nemours.

Economic Appraisal of Research and Development Operations, Thornton Holder, Director of Research, Diamond Alkali Company.

Management Evaluation of New Capital Commitments, John R. Durland, Technical Production Manager, Organic Chemical Division, Monsanto Chemical Company.

Management Evaluation and Control of Manufacturing Operations, Fred V. Gardner, Fred V. Gardner Associates, Milwaukee, Wisconsin.

Chemical Marketing, W. A. Woodcock, Vice President, Sales, Union Carbide International Company.

A paper on nitrogen oxides recovery from waste gases was presented by a chemical engineering student at the recent annual meeting of the **Peninsular Florida Section** *(Robert B. Bennett)*. A. J. Teller, University of Florida, gave up the time for his paper to allow the senior student to be heard. The Section will have one student each year attend the meeting and present a paper, selected in competition with other chemical engineering students at the University.

Also meeting

Wilbur A. Diehl, chief of the General Chemistry Section, U. S. Army Ordnance Missile Command, Huntsville, Alabama, addressed the **Nashville Section** in May . . . Ladies' Night meeting at the **Alton-Wood River Section** in May *(A. W. Frazier)* had Graham Watt, Alton City manager, as guest speaker . . . Donald Katz discussed some aspects of the natural gas industry at the **Detroit Section** *(Cliff Armstrong)* June meeting . . .

Plant tours

Northeastern New York Section *(Walter L. Robb)* visited the Allegheny Ludlum plant at Watervliet, New York, along with local section members of NACE . . . A walking tour of the Houston dock area to observe cargo handling, and a trip on an inspection boat, made up the May meeting of the **South Texas Section** *(W. G. Domask)*. The section members saw the Lyondell plant of Texas Butadiene and Chemical, at Channelview, Texas, in June . . . **Midhudson Chemical Engineers Club** went through the Daystrom plant, precision instrument manufacturers, Poughkeepsie, New York, at the May meeting . . . Climaxing the season's activities, Crown Cork and Seal Company, Baltimore, was viewed by **Maryland Section** members (Philip Messina) on their tour in May.

future meetings

1959—MEETINGS—A.I.Ch.E.

• San Francisco, Calif., December 6-9, 1959. Sheraton Palace. A.I.Ch.E. Annual Meeting. Tech. Prog. Chmn.: C. R. Wilke, Div. of Chem. Eng., Univ. of Calif., Berkeley, Calif. Process Dynamics—E. F. Johnson, Dept. of Chem. Eng., Princeton U., Princeton, N. J. Operations Research—R. R. Hughes, Shell Dev. Co., Emeryville 8, Cal. Progress and Problems in Jet and Rocket Combustion—C. J. Marsel, NYU, University Heights, New York 53, N. Y. Thermal Recovery of Petroleum —F. H. Poettman, Ohio Oil Co., Littleton, Colo. Fundamental Aspects of Chemical Engineering in the Pulp and Paper Industry—J. L. McCarthy, Dept. Chem. Eng., U. of Washington, Seattle, Wash. Turbulence and Turbul nt Mixing—T. Baron, Shell Devel. Co., Emeryville, Cal. Electro-Chemical Engineering —C. W. Tobias, Dept. Chem. Eng. U. of Cal. Berkeley, Cal. Outlook for National Resources —C. Meyer, U. of Calif., Berkeley, Calif. Quality Criteria for Catalytic Cracking Stocks & Methods of Preparation—W. W. Kraft, Lummus Co., 385 Madison Ave., N. Y. 17, N. Y. Fundamental Concepts of Miscible Fluid Displacement—F. H. Poettman, Ohio Oil Co., Littleton, Colo. The Automatic Computer as a Teaching Tool—W. F. Stevens, Ch.E. Dept., Northwestern Univ., Evanston, Ill. Selected Heat Transfer Papers—J. G. Knudsen, Ch.E. Dept., Oregon State Coll., Corvallis, Ore. Heavy Water Production Processes—W. P. Bebbington, Dupont, Aiken, S. Car. Special Lecture Series: Process Development by Statistical Methods (all day Sunday, Dec. 6)—G. E. P. Box & J. S. Hunter, Statistical Rsch. Group, Princeton U., Princeton, N. J. Student Program—D. M. Mason, Stanford U., Calif. Selected Papers—M. Manders, Union Oil Co., Rodeo, Calif. See page 146.

1959—A.I.Ch.E.—Local Section

• Charlottesville, Va. Oct. 23, 1959. Meeting-in-Miniature: New Separation Processes. Central Virginia Section, A.I.Ch.E. Ultra Pure Argon Atmosphere Control—L. S. Gaumer & G. Fedorko, Air Products Co. Ion Exchange Separations—N. W. Frisch, Rohm & Haas Co. Pilot Scale Equip. for Contin. Ion Exchange & Solvent Extraction—I. R. Higgins, Chem. Sep. Corp. & J. T. Roberts, Oak Ridge. Membrane Separations—R. C. Binning, Monsanto. Recent Devel. in Industrial Separations by Ion-Selective Membranes—C. Berger, Ionics Inc. Separation Processes Involving a Chelate Resin—L. J. Lefevre, Dow. For more info: R. M. Hubbard, Ch.E. Dept., Thornton Hall, U. of Va., Charlottesville.

• New York, N. Y. Oct. 27, 1959. Hotel New Yorker. Annual All-Day Symposium, New York Section A.I.Ch.E. What's to be Gained from Computer Control? Chmn.: L. E. Slater, Foundation for Instrumentation Education & Research. Orientation: What is Computer Control?—H. R. Karp, Control Engineering. Computer Manufacturer's Viewpoint—M. Phister, Thompson-Ramo-Wooldridge. Control Engineer's Viewpoint—C. D. Close, Compudyne Control Inc. Chemical Engineer's Viewpoint—R. Hall, duPont. Advances in Separation Techniques. Chmn.: C. M. Thatcher, Pratt Inst. Separation Processes Using Molecular Sieves—G. J. Griesmer & K. Kiyonga, Linde. Performance-Cost Evaluation of Distillation Trays—D. C. Hausch, Shell Oil. Developments in Centrifugation Techniques—F. E. Sullivan, DeLavalle Sep. Co. Panel: What's to be Done to Effect Computer Control? Moderator: T. J. Williams, Monsanto. Panel members to be morning speakers plus invited industr. experts. To iron out differences, arising in morning session. Panel: Customer-Contractor Relations. Moderator: J. A. Hufnagle, Catalytic Construction Corp. Panelists: T. P. Forbath, Cyanamid; W. P. Gage, W. R. Grace; A. Knight, Catalytic Const. Corp.; G. Forbes, Shell Chem. To discuss: What do Contractor & Customer Expect of Each Other?; Are Contract "Extras" Justifiable?; Who Selects the Contractor & Why?; What Kind of Proposal is Best? Audience participation is invited in both panels.

• Galveston, Texas. Oct. 30, 1959. Moody Convention Center. 14th Annual Technical Meeting, So. Texas Section, A.I.Ch.E. Tech. Progr. Chmn.: R. D. Hornbeck, Alcoa. Plastics-Polymerization Sympos. Chmn.: W. B. Howard, Monsanto. Kinetic Considerations in Design of Polymerization Plant:—E. Perry, Monsanto; Mixing, Rates & Power Requirements—A. B. Metzner, U. of Del.; Polymerization Process Research—B. R. Thompson & W. F. Garrett, UCC; Polypropylene—A New Material—J. J. Samuels & I. Leibson, Humble Oil; Instrumentation Sympos. Chmn.: T. B. Metcalfe, Shell Oil; Automation Planning in

continued on page 168

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future meetings

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Chem. Proc. Plants—P. Hart, Dow; **Effect of Increased Instrumentation of Chem. Plants on Maintenance Costs**—A. T. Sherman, duPont; **From Instruments to Computers and Back Again**—C. A. Pfretzschner, Thompson-Ramo-Wooldridge; **Problem of Closure in Distillation and Other Multi-component Systems**—A. M. Peiser, M. W. Kellogg; **Chem. Mfg. Opportunities Abroad Sympos.** Chmn.: C. J. Kramis, duPont; **Foreign Manufacturing—Opportunities & Pitfalls**—E. B. Seaton, Monsanto; **Chemical Opportunity in Brazil**—R. J. Cameron, Cameron & Jones Inc.; **Mexican Chemical Industry—Opportunities and Problems**—P. B. Lorretta, duPont; **Use of Prompt Nuclear Devices for Recovery of Thermal Energy**—H. G. Corniel & A. D. Suttle, Jr., Humble Oil; **General Session** Chmn.: E. H. Hoffing, M. W. Kellogg; **Membrane Permeation—A New Separation Process**—J. F. Jennings, R. J. Lee & E. C. Martin, Amer. Oil; **Safe Design of Flare Stacks for Turbulent Flow**—J. K. Hajek & E. E. Ludwig, Dow; **Fouling and Corrosion in Condenser Tubes**—R. A. McAllister, D. H. Eastham & M. Hollier, Lamar Tech.; **Condensation of a Vapor in Presence of a Non-Condensing Gas**—W. W. Akers, S. H. Davis, Jr., Rice Inst. & J. E. Crawford, Magnolia Petroleum; Group Discussion #1, **Career Counseling**; Moderator: E. C. Holmer, Jersey Production Resch. Center; Group Discussion #2, **Management in Politics**; Moderator: T. A. Wilkner, UCC.

1959—Non-A.I.Ch.E.

• **Cleveland, Ohio. Oct. 5-6, 1959.** Wade Park Manor. **27th Ann. Meeting Engr's. Counc. Prof. Devel.** For info: N. S. Hibshman, Secy. ECPD, 29 West 39 St., New York 18, N. Y.

• **Asilomar, Calif. Oct. 6-9, 1959. International Sympos. High Temp. Technology.** Prog. Chmn.: N. K. Hiester, Dept. 734, Stanford Research Inst. Menlo Park, Calif.

• **Ruston, La. Nov. 5-6, 1959.** Campus La. Polytech. **8th Ann. Instrumenation Conf.** For info: S. Baggarly, M. E. Dept. La. Poly.

1960—MEETINGS—A.I.Ch.E.

• **Atlanta, Ga., Feb. 21-24, 1960.** Hotel Biltmore. **A.I.Ch.E. National Meeting.** Technical Program Chairman: P. Bellinger Georgia Tech, 225 North Avenue, N. W., Atlanta 13, Ga. Student Program: H. C. Lewis, School of Ch.E., Georgia Tech, Atlanta 13, Ga. **Kinetics**, C. D. Holland, Ch. E. Dept. Texas A&M, College Sta., Tex.; **Pesticides**, (2 sessions), D. J. Porter, Diamond Alkali, Box 348, Painesville, Ohio.; **Nuclear Feed Materials Processing**, D. S. Arnold, American Potash & Chemicals Co. Henderson, Nev.; **The Textile Industry**, J. E. Warren, Chem. Div., Goodyear Tire & Rubber Co., Akron 16, Ohio; **High Temperature-Pressure Technology**; H. R. Batchelder, Battelle Memorial Inst., 505 King Ave.; Columbus 1, Ohio; **Mass Transfer Applications in Waste Treatment**, W. W. Eckenfelder, Manhattan College, Riverdale, N .Y. 71, N. Y.; **Filtration**, F. M. Tiller, Dean Coll. of Eng., U. of Houston, Houston 4, Tex.; **Mineral Engineering**, W. A. Koehler, W. Virginia U., Morgantown, W. Va.; **Missiles and Rockets**, R. B. Filbert, Jr., Battelle Memorial Inst., 505 King Ave., Columbus 1, O.; **Selected Papers** (4 sessions Bio-Engrs.; Engrs. Education, Petroleum-Solvents, Management themes.) R. J. Kyle, Eng. Exp. Sta., Georgia Tech, Atlanta 13, Ga.

• **Mexico City, Mexico, June 19-22, 1960.** Hotel Del Prado. **A.I.Ch.E. National Meeting**—Tech. Prog. Chmn.: G. E. Montes, Northern Nat. Gas Co., 2223 Dodge St., Omaha 1, Nebr. **Chemical Engineering in Latin America**—John Mayurnik, Grace Chem. Co., 3 Hanover Square, New York 4, N. Y. **Petroleum and Natural Gas Processing in Mexico & Latin America**—F. W. Jessen, Dept. Petroleum Eng., U. of Texas, Austin, Tex. **Financing International Projects; Optimization-Pitfalls & Potentials**—W. M. Carlson, Eng. Dept., Dupont, Wilmington 98, Del. **Chemical Engineering Education in the Americas**—W. R. Marshall, Jr., U. of Wisconsin, Madison 6, Wisc.; **Food and Biochemicals**—E. L. Gaden, Ch.E. Dept., Columbia U., New York 27, N. Y. **Minerals and Metals**—D. B. Coghlan, Foote Mineral Co., Berwyn, Pa. **Transfer Processes in Two-Phase Systems**—S. G. Bankoff, Cal. Inst. Tech., Pasadena, Cal. **Distillation Equipment**—R. Katzen, 3735 Dogwood Lane, Cincinnati, O. **Pilot Plants**—J. T. Cumming, Penn College, Cleveland 15, Ohio. **Cost Estimation; Selected Papers**—J. A. Samaniego, Shell Devel. Co., Emeryville, Cal.

Deadline for papers: January 19, 1960.

• **Moscow, USSR, June, 1960. 1st Congress of**

continued on page 174

CLASSIFIED SECTION

Address Replies to Box Number care of:
CHEMICAL ENGINEERING PROGRESS
25 West 45th Street
New York 36, New York

SITUATIONS OPEN

Chemical Engineers

3-5 years experience Process Engineering, Production Supervision, Engineering Design or Research in Manufacture Organic Chemicals.

Outstanding Opportunities in New Jersey and Florida locations. Compensation including full employee benefits commensurate with experience.

Send complete resume including salary desired, in full confidence to

Director Technical Personnel
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ECONOMIC EVALUATION ENGINEER

Major West Coast Oil Company with headquarters in Los Angeles has an immediate opportunity for an experienced Chemical Engineer.

Expanding Petrochemical Operations require individual with thorough knowledge of Chemical Processes and Refinery technology with technical competency and creative ability. B.S. Degree required and graduate study in this field is highly desirable.

Submit complete resume covering education, experience, personal data and salary requirements. All replies will be held confidential. Box 2-9

SITUATIONS WANTED

A.I.Ch.E. Members

CHEMICAL ENGINEER—Ph.D. Twenty years' experience petroleum, petrochemicals, organic chemicals, detergents, glyceride oils, polymers; all phases of technical activity both supervisory and independent work, teaching. Desire senior position. Box 8-9.

CHEMICAL ENGINEER—B.Ch.E., 1951. Broad background in development and plant improvement including: pilot plant operation, data correlation, economic evaluation, process design, plant trouble shooting, and cost reduction. Now in junior supervision. Desire more responsibility. Southeast. Box 9-9.

OPERATIONS RESEARCH ENGINEER — B.S. and M.S. in Ch.E., graduate training in Operations Research, mathematics, statistics, computing equipment. Experience as head of Operations Research group. Interest in "Research on Research". Age 39. Box 10-9.

CONSULTING CHEMICAL ENGINEER—desire to trade a fine motel free and clear in the Blue Ridge Mountains of North Carolina for interest in a going chemical company with a technical executive job. Good retirement opportunity. Box 11-9.

CHEMICAL ENGINEER—B.S., 1955. Capable programmer on digital computer, two years' process engineering and two years' production experience. Desire position utilizing the computer experience. Box 12-9.

CHEMICAL ENGINEER—M.S.Ch.E. 1951. Six years' successful experience in process and product development, pilot plant (detergents, vegetable oils). Patents. Current salary $10,000. Seek challenging position in large or medium size company. Box 13-9.

(continued on page 171)

OPENING IN
PRODUCTION ENGINEERING RESEARCH
AT
THE PURE OIL COMPANY
RESEARCH CENTER
CRYSTAL LAKE, ILLINOIS

CHEMICAL ENGINEER, M.S. or Ph.D., with strong background in fundamental science and mathematics. Experience desirable. This man is needed to conduct research on development of improved oil recovery techniques and reservoir evaluation methods and to apply these techniques and methods to reservoirs.

Production engineering is an expanding activity at a modern laboratory located near Chicago. Excellent living and working conditions. Attractive salary and company benefits.

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MR. D. M. DAWES
THE PURE OIL COMPANY
Research Center
Crystal Lake, Illinois

Research and Development Engineers, $6,300-10,000 per year. Robert A. Taft Sanitary Engineering Center, U. S. Public Health Service, Cincinnati, Ohio, needs project engineers and project leaders for studies in air pollution. Competitive federal career civil service requirements and benefits apply. Prefer experience in research and development. Submit resume.

ARMY RESEARCH OFFICE

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ARMY RESEARCH OFFICE

Office, Chief of Research and Development
Washington 25, D. C.

ARMY RESEARCH OFFICE

PROJECT ENGINEER

Chemical or Mechanical Engineer to work in our Central Engineering Department, Cleveland, Ohio. Project engineering experience in the chemical industry desired. Work will vary from studies of proposed projects to execution of the final engineering construction and plant start-up.

Excellent employee benefits and salary program. Opportunities for professional growth.

You are invited to submit a resume for our confidential and prompt consideration to:

William L. Abele
Diamond Alkali Company
300 Union Commerce Building
Cleveland 14, Ohio

Process Development Engineers

We are conducting an intensive search for top flight synthetic fiber process development engineers. Due to the critical nature of our program, we can consider only men of the highest technical and personal caliber.

These men will work as key members of a project team to develop and improve methods and equipment, and conduct and supervise pilot plant tests and trials.

We seek a true development man; but more than this we want a man with the innate flexibility and intelligence to be successful as well in research, product development or other areas. Above all, we want a *PROMOTABLE* man. The candidate selected for a senior position should have immediate potential for *PROJECT LEADER.*

BS, MS, or PhD in ChE, ME, or Chemistry strongly preferred. SYNTHETIC FIBER EXPERIENCE MANDATORY

Please send your résumé, in confidence, to Mr. P. M. Townsend.

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P. O. Box #1414
Charlotte 1, North Carolina

OPENINGS IN
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COLUMBIA UNIVERSITY

Research Engineers: Research in Heat Transfer related to Nuclear Reactors. M.S. or Ph.D. in Chem. or Mech. Eng., experience in experimental and/or pilot plant work and good grounding in theoretical aspects of engineering science, essential. Starting salary range: Open

Engineering Supervisor: To supervise and coordinate shop, technician, and draftsman services related to performance of various research projects and to assist in design of apparatus. Eng. degree and experience in operation and design of flow loops and related equipment essential. Experience in drafting and shop practices desirable. Starting salary range: $8,000-$9,000/yr.

Engineering Assistant: Training as draftsman, interest in photography and mechanical design, and ability to learn, essential. Starting salary range: $350-$450/mo.

U. S. citizenship required. Benefits include tuition exemption and liberal vacation policy.

Send resume to:

MRS. F. J. McNALLY
HEAT TRANSFER RESEARCH FACILITY
632 West 125th Street
New York 27, New York

Do not telephone

HEAT TRANSFER ENGINEER

0-5 years experience in the thermal design of process heat exchangers. Work schedule can permit attendance in graduate courses at universities in and near Philadelphia and Newark, Delaware. Submit details of education, experience, earnings and professional references to J. R. Piersol, Personnel Manager, Downingtown Iron Works, Inc., Downingtown, Penna.

CHEMICAL ENGINEER

Ph.D. in Fuel Technology (not nuclear). Position includes studies in Theory and Practice of Carbon Activation, design and supervision of laboratory and pilot scale units and checking out of theories through plant studies.

Carbon Research Division
WEST VIRGINIA PULP & PAPER COMPANY
Personnel Manager
Tyrone, Pa.

OPPORTUNITY KNOCKS

There is an opportunity in our New York office for a young chemical engineer who thinks his real field is in selling. We are one of America's oldest and most firmly established manufacturers of corrosion-resistant materials and equipment. Our products cover a wide segment of industry and are accepted as top quality everywhere. The man we want should be in his late twenties or early thirties. We would be happy if he has had selling experience to industrial accounts. He must have the ability to meet and discuss products with technical and purchasing personnel. It's an attractive job right now—will be more attractive as the years go by.

Please tell us all about yourself in a letter. Interviews will be arranged in New York. 1-9

PILOT PLANT ENGINEER

Opportunity for Chemical Engineer, recent graduate, for process development in conjunction with expanding organic chemical manufacturing division. Company located in semi-rural community in Central New York State with modern laboratories and complete benefit program.

Please forward resume to:

Professional Employment Manager
EATON LABORATORIES DIVISION
THE NORWICH PHARMACAL COMPANY
Norwich, New York

SITUATIONS WANTED

A.I.Ch.E. Members

(continued from page 169)

CHEMICAL ENGINEER—B.Ch.E., desire part-time or consulting position in N. Y., N. J., Conn. area. Available 1-2 days per week. Licensed P.E. in N. Y. and N. J. Extensive industrial and academic experience. "Q" cleared. Box 14-9.

CHEMICAL ENGINEER—M.S.Ch.E. Age 28. Four years' experience R & D and pilot plant in organics, special fuels, plastics and adhesives. Seeking technical and administrative position with dynamic company. N. J. and N. Y. C. preferred; others considered. Box 15-9.

SEEKING BROADER RESPONSIBILITIES—professionally licensed chemical engineer, M.Sc., 1949; M.B.A., 1958. Ten years' diversified experience process, project development, design, economic evaluation, production supervision; fine chemicals, petrochemicals, refining. Prefer company offering professional growth opportunities located in New York Metropolitan area. Box 16-9.

TECHNICAL MANAGEMENT—Business oriented and trained Ph.D. Chemical Engineer. Seven years' intensive experience in research, production and development. Box 19-9.

CHEMICAL ENGINEER—M.Sc., age 34, patents, diversified experience petroleum refining units process design, process supervision, development, trouble shooting. Six years' contractor, five years' catalytic process licensor. Desire technical sales or engineering position. Metropolitan New York. Box 20-9.

CHEMICAL ENGINEER—B.Ch.E., 46., refinery and petrochemical plants project manager, perfect German, some Dutch and Russian, seek project manager position in Germany where now on engineering assignment. Box 22-9.

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SITUATIONS WANTED

A.I.Ch.E. Members

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CHEMICAL ENGINEER—B.S.Ch.E. Fourteen years' experience process design and development, production, and liaison engineering in the pharmaceutical and chemical industry. Seek challenging position in process engineering or production with chemical manufacturer. Box 21-9.

CHEMICAL ENGINEER—B.Ch.E. Ten years' experience in applied research, product and process development including resin coatings, product evaluation and process engineering. Seek challenging position with expanding concern. Prefer Northeast or Midwest. Box 23-9.

CHEMICAL ENGINEER—M.S. 1953, age 28, family. Three years' development and technical writing in specialty chemicals. Three years' USAF develoment testing in nuclear weapon support. Seek development or related position in Southwest or West. Box 24-9.

CHEMICAL ENGINEER—B.S., eleven years' diversified experience, research, development, quality control, technical service. Accept responsible and challenging job in management, research or engineering. Prefer inorganic field. Five-figure salary required. Box 25-9.

CHEMICAL ENGINEER—B.S.CH.E., 1952, age 29. Process and plant design, economic evaluations, development and start-up, supervisory background. Desire responsible position with growing organization. Box 26-9.

PROCESS ENGINEER—B.Sc. Chem. Eng. Experience in process design and construction of chemical plants. Presently in charge of sulphate pulp process controls. Desire relocation. Box 27-9.

TECHNICAL - SCIENTIFIC MANAGEMENT—position desired by Ph.D. Chemical Engineer with broad background in R & D, engineering, teaching. Substantial record in project management, process evaluation and design, economic feasibility studies, consultation, reactor engineering. $18,000 plus range. Box 28-9.

SPECIAL NOTICE

Effective July 1, 1959. Members of the American Institute of Chemical Engineers in good standing are allowed TWO sixline Situation Wanted insertions (about 36 words) free of charge per year.

ADVANCE INFORMATION

The Situations Wanted portion of this Classified Section is preprinted and mailed a few days in advance of publication, to Employment Directors. Send names of individuals who should be on mailing list to: Miss E. Adelhardt, Chemical Engineering Progress, 25 W. 45th Street, New York 36, New York.

A Preprint of all SITUATIONS WANTED notices is mailed directly monthly to thousands of personnel and recruitment officers nationally.

CLASSIFIED SECTION RATES

Advertisements in the Classified Section are payable in advance at 24c a word, with a minimum of four lines accepted. Box number counts as two words. Advertisements average about six words a line. Members of the American Institute of Chemical Engineers in good standing are allowed two six-line Situation Wanted insertions (about 36 words each), free of charge a year. Members may enter more than two insertions at half rates. Prospective employers and employees in using the Classified Section generally agree that all communications should be acknowledged as a matter of courtesy but recognize circumstances where secrecy must be maintained. Answers to advertisements should be addressed to the box number. Classified Section, Chemical Engineering Progress, 25 West 45th Street, New York 36, N. Y. Telephone COlumbus 5-7330. Advertisements for this section should be in the editorial offices the 15th of the month preceding publication.

Classified . . . EQUIPMENT SECTION

ENGINEERING SOCIETIES PERSONNEL SERVICE, INC.

(Agency)

New York	Chicago	San Francisco
8 West 40th St.	27 East Madison St.	57 Post St.

These items are listings of the Engineering Societies Personnel Service, Inc. This Service, which cooperates with the national societies of Chemical, Civil, Electrical, Mechanical, Mining, Metallurgical and Petroleum Engineers, is available to all engineers, members and non-members, and is operated on a nonprofit basis. If you are interested in any of these listings, and are not registered, you may apply by letter or resume and mail to the office nearest your place of residence, with the understanding that should you secure a position as a result of these listings you will pay the regular employment fee of 5% of the first year's salary if a non-member, or 4% if a member. Also, that you will agree to sign our placement fee agreement which will be mailed to you immediately, by our office, after receiving your application. In sending applications be sure to list the key and job number.

When making application for a position include eight cents in stamps for forwarding application to the employer and for returning when possible.

A weekly bulletin of engineering positions open is available at a subscription rate of $3.50 per quarter or $12 per annum for members, $4.50 per quarter or $14 per annum for non-members, payable in advance.

Positions Available
New York Office

CERAMIC PROJECT ENGINEER, B.S. or M.S. in chemical engineering, ceramics or chemistry, with two to five years' experience in research on ceramics and/or graphite for reactors, particularly fuel elements for high-temperature gas-cooled reactors. Salary open. Company pays placement fee. Location, Ohio. W-7917.

PRINCIPAL PROCESS ENGINEER, chemical engineering graduate, with at least ten years' process and evaluation experience in heavy and fine chemical fields. Salary, $15,000 a year. Location, New York, N. Y. W-7903.

PROCESS ENGINEER, chemical or mechanical graduate, with planning, production and operations supervision in food or allied fields. Salary, $8,000-$10,000 a year. Location, New York, N. Y. W-7871.

ENGINEERS, graduate chemical, with strong background in industrial instrumentation and process control; experience as engineers in the chemical, petroleum, gas or power industries. Sales minded, able to work with field sales personnel, customers and home plant engineering departments. Travel about 25% of time. Salary based on education, experience and abilities. Headquarters, Massachusetts. W7857.

PROJECT ENGINEER, chemical or mechanical, with process design background; a minimum of three years' process design experience, and field experience in either plant construction, operations or start-up. Salary, $8000-$9500 a year. Location, New York, N. Y. W7836.

CHEMICAL ENGINEER, graduate, to organize a chemical engineering division to specifically handle wet scrubbers; then to branch out into dry collection of dusts and the handling of gases by means of special fans. Apply by letter giving complete information and salary requirements. Location, Connecticut. W7820.

INSTRUMENTATION ENGINEER, graduate chemical or mechanical engineer, with ten to fifteen years' experience, to design, specify instrumentation and trouble-shoot for heavy chemical processes. Salary, $9400-$10,800 a year. Location, New York, N. Y. W7828.

ENGINEERS, (a) Process Design Engineers, graduate chemical, with five to ten years' experience in process design engineering covering new processes, expansions and modernizations. Salary, to $10,800 a year. (b) Project Engineer, graduate chemical or mechanical, with at least five years' experience in design and equipment selection, estimating materials and labor costs. Salary, $7800-$9600 a year. Location, South. W7827.

CHEMICAL ENGINEER, B.S. or M.S. in chemical engineering, with one to three years' experience in staff or supervisory plant or laboratory function. Must have a strong process control and instrumentation background; process involves polymer chemistry and utilizes a resin bonding concept. Will perform plant duties in developing new formulation and processing procedures and improving present procedures. Salary, $6500-$7200 a year. Location, Southwest. W7777(a).

PROJECT ENGINEER, chemical engineering graduate, with at least five years' experience on sugar refining and processing. Knowledge of Spanish desirable. Salary, $8000-$10,000 a year. Location, East. W7629.

SALES ENGINEER, graduate chemist or chemical engineer, preferably with several years' experience with fatty acids, tall oil or turpine products. Salary, about $7800 a year. Territory, Michigan, Ohio, Indiana and Kentucky. W7618.

CHEMICAL ENGINEER, thoroughly familiar with heat transfer and with a creative urge to design process equipment. Position will involve some experimental laboratory work. Company does extensive work involving the design of special equipment related to ovens and furnaces as well as chemical and industrial process equipment. Some customer contact. Some travel. Permanent. Salary open. Company will pay relocation expenses. Location, Virginia. W7583.

ASSISTANT GENERAL MANAGER for chemical manufacturer, degree in chemical engineering or equivalent in experience, to assist in all phases of management, including supervision of production, purchasing, warehousing, sales, traffic, credit, inventory control, plant maintenance. Salary, $10,000 a year. Company will pay placement fee. Location, New York suburban area. W7568.

PROJECT ENGINEER, mechanical or chemical graduate, with five to ten years' experience in chemical plant design and construction. Must have previously worked as project engineer. Salary, to $13,000 a year. Location, New York, N. Y. W7536.

CHEMIST OR CHEMICAL ENGINEER, educated in and experienced in paper chemistry. Some working knowledge of the conversion of paper and paper board; and the basic properties of coatings, adhesives, film and foils. Job in laboratory and pilot plant, experimental and test, for production in paper packaging. Location, northern New Jersey. W7464.

San Francisco Office

PROJECT ENGINEER, Building Materials Process, chemical, engineering graduate, 30-38, with three to ten years' experience in work related to central engineering department planning for multi-plant operations for manufacturer of building materials, roofing, paper board or paper products. Capable of handling planning, layouts, specifications for plant construction, expansion, modifications for increased production, improvement at pilot or operational stages. Potential to develop into project man, superintendent, manager or plant engineer. Salary, $600-$700 a month. San Francisco East Bay. S(P)-4557R.

ORGANIC CHEMISTS, Basic Chemical Industry, B.S., M.S. or Ph.D. in chemical engineering, chemistry, with or without experience, to work in research laboratory of large company. Salary dependent upon experience. Southern California. S(P)-4546(a).

ASSISTANT MANAGER, Research Laboratory, Ph.D. in chemical engineering, with good supervisory experience in chemical industry. Salary open. Southern California. S(P)-4545(b).

CHEMICAL ENGINEERS, (a) Market Development Analyst, basic chemical industry, chemical engineer or chemist, preferably with MBA, with three years' experience in market development if possible. Salary, about $575-$600 a month. (b) Market Development Representative, chemical engineer or chemist, preferably with MBA, and five to eight years' market development experience. Salary, $750 a month. (c) Manager, Market Development Section, chemical engineer or chemist, preferably with MBA, 30-45, with eight to twelve years' chemical market development experience. Salary, $1100-$1400 a month. Southern California. S(P)-4543.

CORROSION ENGINEER, Water Systems, chemical or mechanical engineering graduate (Registered preferred); 30-40. Qualified by experience to provide technical experience to clients relating to the sales, application and usage of chemical and equipment to inhibit corrosion in water systems and supplies in buildings, institutions or industry, for well established representative. Primarily sales engineering work. Car required. Salary, $700 a month plus $75 a month for car. San Francisco Peninsula. S(P)-4509.

RESEARCH SUPERVISOR, Adhesives, chemical engineer or chemist, with considerable research experience and some production experience in adhesives and gluing processes; some coating or wood finishing experience desirable. Under general supervision of Director, will plan, develop and administer research on adhesives, gluing processes and glued products for large manufacturing company. Salary, $775-$1000 a month to start. S(P)-4460R.

CHEMICAL ENGINEER, heavy chemicals, B.S., with to five years' experience and with definite qualifications as potential production superintendent after preliminary training in process development department of a large processing plant. Must be able to work with plant personnel. Recent graduate given consideration. Salary, $485-$575 a month, depending upon experience. San Francisco East Bay. S(P)4447.

RESEARCH COMPUTER ENGINEER, experienced chemical or mechanical engineer, or applied physicist, with good background in math. Computer experience desired. Work consists of analysis and programming of engineering problems for Datatron 205 computer in research division. Apply by letter. Employer will negotiate placement fee. Salary open. Southern California. S(P)-4437.

future meetings

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International Fed., Automatic Control. To cover areas of **Theory, Hardware & Applications of Automatic Control.** U.S. participation sponsored by American Automatic Control Council. Affiliated societies: **A.I.Ch.E., ASME, AIEE, IRE, ISA.** A.I.Ch.E. Chmn: D. M. Boyd. Universal Oil Prods., Des Plaines, Ill.

• Tulsa, Okla., Sept. 25-28, 1960. Hotel Mayo. **A.I.Ch.E. National Meeting.** Tech. Prog. Chmn.: K. H. Hachmuth, Phillips Petroleum Co., Bartlesville, Okla. **Transport Processes in Petroleum Recovery**—L. P. Whorton, Atlantic Refining, Box 2819, Dallas 1, Texas; **Natural Gas & Natural Gas Liquids**—R. L. Huntington, U. of Oklahoma, Norman, Okla. **Advances in Refinery Technology**—W. C. Offutt, Gulf R&D Co., P.O. Drawer 2038, Pittsburgh 30, Pa. **Petrochemicals**—C. V. Foster, Continental Oil Co., Ponca City, Okla. & H. L. Hays, Phillips Chem. Co., Bartlesville, Okla. **Piloting, or Why Buy the Restaurant When All You Need is a Meal**—R. E. Weis, Phillips Pet. Co., Bartlesville, Okla. & D. Popovac, Continental Oil Co., Ponca City, Okla. **Corrosion & Materials of Construction**—W. A. Luce, The Duriron Co., P.O. Box 1019, Dayton 1, O., & M. S. Worley, Black, Sivalls & Bryson, P.O. Box 1714, Oklahoma City, Okla. **Statistics and Numerical Methods Applied to Engineering**—R. L. Heiny, 2709 Jefferson, Midland, Mich. **Air & Ammonia Plant Safety**—L. T. Wright, Standard Oil (Ind.) Whiting, Indiana. **Refinery & Natural Gasoline Plant Safety; Processing Agricultural Products**—A. Rose, Tex. Eng. Exp. Sta., Tex. A&M, Coll. Sta., Tex. **Area Industries. Chemical Reactions Induced or Modified by Radiation**—J. J. Martin, Ch.E. Dept., U. of Mich., Ann Arbor, Mich. **Conservation & Utilization of Water**—F. J. Lockhart, Ch.E. Dept., U. of So. Cal., 3551 University Ave., Los Angeles 7, Cal. **Foams**—C. S. Grove, Jr., Syracuse U., Syracuse 10, N. Y. & R. L. Tuve, U.S. Naval Rsch. Lab., Wash. 25, D.C. **Computers as a Management Tool**—R. Cziner, Grace Chem. Co., 3 Hanover Square, New York 4, N. Y. **Non-Newtonian Fluid Mechanics**—A. B. Metzner, U. of Delaware, Newark, Del. **Student Program. Selected Papers.**

Deadline for papers: May 2, 1960.

• Washington, D. C., Dec. 4-7, 1960. Statler Hotel. **A.I.Ch.E. Annual Meeting.** Tech. Prog. Chmn.: D. O. Myatt, Atlantic Research Corp., Alexandria, Va.

Tentative Program framework: **Chemical Engineering in Govt. Programs.** Agency Oriented: **Nuclear Energy, Health and Education; Agriculture; Foreign Assistance Programs; Resource Development; Utilization and Reclamation; Naval Warfare Technology; Land Warfare Technology; Chemical Warfare, and Basic Research.** Subject Oriented: **Doing Business with the Government; Fluid Particles and Aerosols; Combustion; Materials Deterioration; New Process Techniques; Unsteady State Instrumentation; Computer Control of Processing Units; Missiles and Rockets; Design Techniques for Very Large Systems Information and Communication; Characteristics of Portable and Expendable Plants and Equipments.**

Deadline for papers: July 5, 1960.

• New Orleans, La. Feb. 26-Mar 1, 1961. Hotel Roosevelt. **A.I.Ch.E. National Meeting.** Tech. Prog. Chmn.: H. L. Malakoff, Petroleum Chem. P.O. Box 6, New Orleans 6, La. **Kinetics of Catalytic Reaction; Brainstorming Technical Problems; Petrochemicals—Future of the Industry on Gulf Coast; Future Processing Technologies in the Petroleum Industry; Education and Professionalism; Mathematics in Chemical Engineering; Liquid—Liquid Extractions; New Processes in the Area; Water from Sea Water; Materials of Construction; Evaluation of Research & Development Projects; Flow Through Porous Media.**

Deadline for papers: Sept. 5, 1960.

• Cleveland, O., May 7-10, 1961. Sheraton-Cleveland. **A.I.Ch.E. National Meeting.** Tech. Prog. Chmn.: R. P. Dinsmore, Goodyear Tire & Rubber Co., Akron 10, O.

Unscheduled Symposia

Correspondence on proposed papers is invited. Address communications to the Program Chairman listed with each symposium below.

Computers in Optimum Design of Process Equipment: Chen-Jung Huang, Dept. of Chem. Eng., Univ. of Houston, Cullen Blvd., Houston 4, Texas.

Solar Energy Research: J. A. Duffie, Director of Solar Energy Laboratory, Univ. of Wisconsin, Madison, Wis.

Hydrometallurgy—Chemistry of Solvent Extraction: O. H. Beyer, Dept. of Chem. Eng., Univ. Mo., Columbia, Mo.

Process Dynamics as They Affect Automatic Control—D. M. Boyd, Universal Oil Prods., Des Plaines, Ill.

Nuclear Chemical Plant Safety—C. E. Dryden, Ohio State U., Columbus, O.

Nuclear Reactor Operations—R. L. Cummings, Atomics International, P.O. Box 309, Canoga Park, Cal.

Drying—R. E. Peck, Ill. Inst. of Tech. 330 So. Federal, Chicago, Ill.

Author Information

Procedure in submitting papers.

1. Obtain four copies of "Proposal to present a paper before the A.I.Ch.E.," plus one copy of "Guide to Authors" from Secretary, A.I.Ch.E., 25 West 45th St., New York 36, N. Y.
2. Send one copy of completed form to Technical Program Chairman for meeting selected from above list.
3. Send another copy to Norman Morash, Titanium Div., Natl. Lead Co., So. Amboy, N. J. (Ass't. Chmn. Program Comm.)
4. Send third copy to Editor, Chemical Engineering Progress, 25 West 45th St., New York 36, N. Y. Paper will automatically be considered for possible publication in A.I.Ch.E. Journal.
5. If desired to present paper in a selected symposium send fourth copy to chairman of the symposium.
6. Prepare six copies of manuscript. Send all six to Symposium chairman or the Selected Papers chairman, whichever is appropriate.

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Philadelphia 2—Lee W. Swift, Jr., Dist. Mgr., 1207 Broad-Locust Bldg. PEnnypacker 5-5560.

Chicago 4—Martin J. Crowley, Jr., Dist. Mgr.; Robert Kliesch, Dist. Mgr.; 53 West Jackson Blvd., Room 504, HArrison 7-3760.

Cleveland 15—Harry L. Gebauer, Dist. Mgr., 1501 Euclid Ave., SUperior 1-3315.

Pasadena 1, Calif.—Richard P. McKay, Dist. Mgr., 465 East Union St., MUrray 1-0685.

Dallas 18—Richard E. Haierman, Dist. Mgr., 9006 Capri Drive, Diamond 8-1229.

Birmingham 9, Ala.—Fred W. Smith, Dist. Mgr., 1201 Forest View Lane, Vesthaven, TRemont 1-5762.

News and Notes of A.I.Ch.E.

Guide to Kanawha—The Committee on Professional Development of the Charleston Section of the A.I.Ch.E. under its chairman, W. R. Manning, has developed an important engineering service for companies in the Kanawha Valley. This group in combination with special committees of the Civil, Mechanical, and Electrical Engineers turned out an engineer's guide to the area which covers such subjects

as housing, housing costs, recreational facilities, churches and schools, local statistics, etc., a very important orientation publication for anyone contemplating living in that area and one of considerable help in those important first five years after a man graduates from his professional school.

Student guidance—High school students in the New Jersey area and guidance officers are constantly kept informed of the activities of guidance groups through the New Jersey Engineers' Committee for Student Guidance. This group travels throughout the state of New Jersey, telling high school students the facts about careers in the engineering fields. Recently its activities have been summarized in a release from the Newark College of Engineering. Last year the group sent 232 speakers—17 panels, 61 single speakers, and 14 student teams from Princeton, Rutgers, Stevens, and the Newark College of Engineering—to a total of 101 high schools in the state of New Jersey, the meetings being attended by over 11,000 students who are interested in learning more about the technical fields. For other Local Sections that want to try this, the retiring chairman of the New Jersey group, Ralph Cohen, a chemical engineer with Hoffmann-La Roche in Nutley, New Jersey, will be glad to answer questions.

Another equally successful program in student guidance was held in Philadelphia. Norton H. Walton, of the Atlantic Refining Company, was chairman of the Guidance Committee for the technical societies in that city. In addition to school guidance meetings, 6,000 students heard about engineering from 92 speakers. This group holds Saturday morning science, engineering, and technology sessions for gifted students in the eleventh grade (331 students from 68 different schools participated this year), does individual counseling, holds Saturday morning trips for industrial science teachers, has aided in the founding of four additional junior engineering and technical societies, and supplied panel members for part of a six-week TV engineering program.

All in all, I believe that the chemical engineers are doing more than their share in providing guidance activities in a very critical area—mostly without fanfare, wthout millions of dollars being poured into it from government coffers—and probably doing as sincere and intelligent a job as any guidance work being done in the country today. The companies themselves are cooperating by making the time of their engineers available and should any supervisor or employer of chemical engineers receive a request from a Local Section or from one of his chemical engineers associated with a Local Section engaged in this work, will he please recognize its importance and support it happily.

Chicago TV—We reported before about the Chicago Section and the TV program it helped to sponsor. According to Hank Nolting, the section has six 16-mm. sound films of these programs, one of them being a summary for the entire series This latter film probably will be shown to Council at St. Paul. Look on the bulletin board at the meeting for any announcement concerning a general showing of this film.

Southern California directory—Hugh A. Baird, Secretary of the Southern California Section, sends along a directory published for the second year by the section. It gives pertinent information about all members plus pictures of the officers, advertisements and advertising directory, local company offices by products, plus three pages of various conversion tables. All in all, it is an excellent job and represents an enormous amount of work.

Texas biggest—Now that the East Texas Section is a Local Section, the State of Texas has pulled ahead of both New York and Ohio in the number of local groups within the state. Texas now has six; New York and Ohio have five each. However, a new group considering formation at Beacon, New York, will create another tie for first place.

A. I. Ch. E. – A. C. S. scholarship – Cooperation between the chemists and chemical engineers in the Charleston area will give a $1,000 scholarship to some deserving Kanawha County high school student to study science or engineering at a college of his choice. The A.I.Ch.E. and A.C.S. local sections got together, the chemical engineers contributing $639.55 and the A.C.S. $500 toward the goal. This was culled from a final report sent to me by G. E. Merryman, Jr. M. M. DeLancy, R. L. Stearns, and R. L. Yelton were the Scholarship Committee.

Employment pointers—Chemical engineers who are looking for a job might be interested in a brand-new publication of A.I.Ch.E., "Employment Pointers for Chemical Engineers." To get it, just drop a note to this office.

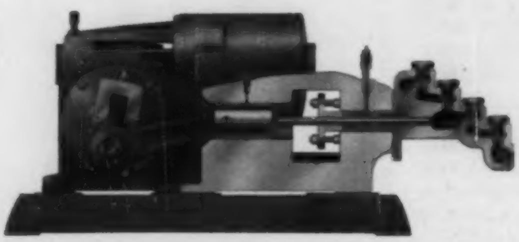
Directory supplement—A new listing of the committees of the Institute, correct to July 15 of this year, has just been issued. We are including it in all directories being sent out. Members who want either a directory or a corrected supplement need only drop us a post card. F.J.V.A.

HOW TO METER SLURRIES ACCURATELY

Few pumping jobs present more complex problems than the accurate metering of slurries. Since they are often abrasive, slurries can make the selection of pump parts extremely difficult. Minute particles settling out in the packing can score a plunger beyond usefulness in minutes. And viscous, tacky slurries can limit ball check freedom and reduce accuracy. But even the toughest slurries *can* be metered accurately . . . by adhering to good slurry handling practice, and by choosing the right pump for the job.

Keep Slurries In Suspension

Several practices that have proved valuable in this difficult service are aimed at keeping the solids in suspension. Suction and discharge lines should be as short as possible. The supply tank should always be well agitated. And if packed plunger pumps are used, stroking speed should be held between 45 and 75 rpm to minimize settling.



Standard Motor Driven Controlled Volume Pump

Choosing The Right Pump

Controlled volume pumps are manufactured in a sufficient variety of designs to provide a full range of desired characteristics for slurry service. An economy pump such as Milton Roy's H20® can handle slurries up to 5% by weight. Standard motor driven pumps, with minor modification, can handle much denser slurries. And the new ODS (Oliver Diaphragm Slurry*) controlled volume pump can easily manage slurries containing up to 60% solids by weight.

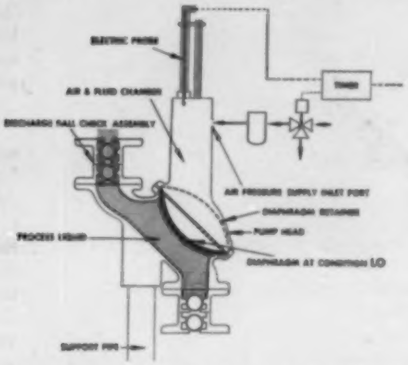
*Manufactured under exclusive license granted by Dorr-Oliver Inc.

Packed Plunger Pumps

Because the entire liquid end of a packed plunger pump is in intimate contact with the slurry, considerable attention must be paid to materials selection. Ball checks and plunger should be as hard as possible, and seats should be relatively soft. Balls are usually made of Hastelloy D, 440 stainless, or ceramic, while 316 stainless is standard for the seats. The plunger must be extremely hard, and high strength sintered alumina is generally recommended.

Proper packing maintenance in slurry service demands that packing be flushed out continuously. An internal flush, continuously bleeding a small amount of liquid along the plunger, is the most common. Dangerous liquids may require an external flush arrangement. Liquid is continuously fed in on one side of the lantern ring, drawn around the plunger, and carried away from the other side.

The ODS Controlled Volume Pump



Capable of pumping 180 gph of the densest slurries at accuracies of ± 2% against pressures up to 90 psi, the ODS has no plunger, no packing. It is based on the Oliver Diaphragm Slurry pump design principle which consists of two opposed chambers separated by a slack diaphragm. A three-way solenoid alternately pressurizes and bleeds air from the upper chamber. With the upper chamber at atmospheric pressure, the suction head forces slurry into the lower chamber. Then, when the upper chamber is pressurized, the diaphragm forces the slurry out through the specially designed ball check valves.

Problem Slurries

Yes, slurries *can* be metered accurately. And the best proof of this claim is the thousand or more Milton Roy pumps successfully metering slurries in the field. The list includes such problem liquids as an 80% coal slurry, a 45% suspension of lead peroxide in butyl phthalate, 15 to 20% diatomaceous earth slurries, finely divided nickel catalytic suspensions, gold ore slurries, and even a 55% by weight powdered aluminum suspension. Some of these materials are so thick that they can support the weight of a screwdriver.

If precision metering of slurries is one of your problems, look again to Milton Roy's 25 years of experience for your most economical solutions. Write for a general introduction to controlled volume pumping given in Catalog 553-1, Milton Roy Company, 1300 East Mermaid Lane, Phila. 18, Pa.

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For more information, turn to Data Service card, circle No. 42